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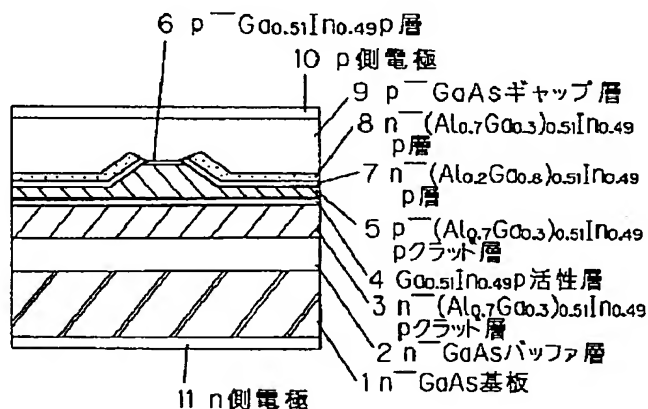
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(54)【発明の名称】 半導体レーザおよびその製造方法

(57)【要約】

【目的】 可視光領域に発振波長を有する半導体レーザに関するもので、外部微分量子効率が高く、また横モードの安定性の高い高出力の半導体レーザを提供する。

【構成】 半導体レーザの $p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ Pクラッド層5の一部が台形状のストライプであり、ストライプの外部の $p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ Pクラッド層5上に $n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}$ P層7、 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層8を積層した構造を有し、台形状のストライプの内部の実効屈折率がストライプの外部の実効屈折率より0.02低くなっている。



【特許請求の範囲】

【請求項1】半導体基板、及び該半導体基板上に形成された積層構造であって、活性層と、該活性層を挟む一対のクラッド層と、該活性層のストライプ状所定領域に電流を注入するための電流狭窄層とを有する積層構造、を備えた半導体レーザであって、該電流狭窄層は、該活性層の該所定領域に対応する領域以外の領域に形成された第1電流ブロック層を備えており、該第1電流ブロック層は、該一対のクラッド層の屈折率よりも高い屈折率を有する半導体層であって、該活性層の禁制帯幅よりも広い禁制帯幅を有している半導体レーザ。

【請求項2】請求項1に記載の半導体レーザであって、前記一対のクラッド層のうち、前記活性層よりも上方に位置するクラッド層は、該半導体レーザの共振器方向に沿って延びるストライプ状リッジを有しており、前記第1電流ブロック層は、該ストライプ状リッジを有する該クラッド層上において、該ストライプ状リッジ以外の領域を覆っている半導体レーザ。

【請求項3】前記電流狭窄層は、前記第1電流ブロック層上に設けられた第2電流ブロック層を更に備えており、

該第2電流ブロック層は、前記活性層の禁制帯幅よりも広い禁制帯幅を有している半導体層である請求項2に記載の半導体レーザ。

【請求項4】前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、台形である請求項3に記載の半導体レーザ。

【請求項5】前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、長方形である請求項3に記載の半導体レーザ。

【請求項6】前記半導体基板は、GaAsから形成されており、

前記活性層は、GaInPから形成されており、前記第1及び第2電流ブロック層、ならびに前記一対のクラッド層は、AlGaInPから形成されている請求項3に記載の半導体レーザ。

【請求項7】前記活性層は、多重量子井戸構造を有している請求項1に記載の半導体レーザ。

【請求項8】前記一対のクラッド層のうちの一方は、前記第1電流ブロック層を挟みこむ第1層部分及び第2層部分を有している請求項1に記載の半導体レーザ。

【請求項9】前記半導体基板は、GaAsから形成されており、

前記活性層は、InGaAs層を含んでおり、前記一対のクラッド層は、GaInPから形成されており、

前記第1半導体層は、GaAsから形成されている請求項8に記載の半導体レーザ。

【請求項10】前記活性層は、多重量子井戸構造を有し

ている請求項8に記載の半導体レーザ。

【請求項11】半導体基板上に積層構造を形成する工程を包含する半導体レーザを製造する方法であって、該工程は、更に、

第1クラッド層を形成する工程と、

該第1クラッド層上に活性層を形成する工程と、該活性層上に第2クラッド層となる膜を形成する工程と、

該膜の一部を選択的にエッチングすることにより、該半導体レーザの共振器方向に延びるストライプ状リッジ部を該膜に形成して、それによって第2クラッド層を形成する工程と、

該第2クラッド層のうち該ストライプ状リッジ部以外の部分の上に、該第2クラッド層の屈折率よりも高い屈折率を有し、かつ、該活性層の禁制帯幅よりも広い禁制帯幅を有している第1半導体層を形成する工程と、

該第1半導体層上に、該活性層の禁制帯幅よりも広い禁制帯幅を有している第2半導体層を形成する工程と、を包含する半導体レーザの製造方法。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、発光効率が高く、基本横モードの安定性に優れた高出力の半導体レーザおよびその製造方法に関するものである。

【0002】

【従来の技術】可視光領域でレーザ発振を生じて発光する半導体レーザは、レーザ・ビーム・プリンターや光ディスク等の光情報処理用光源などの用途があり、最近その重要性を増している。中でも、 $(Al_xGa_{1-x})_{0.5}In_{0.5}P$ 系の材料は、良質の基板材料であるGaAsに対して格子整合し、組成xを変化させることで0.68μmから0.58μmの範囲内の任意の波長を有するレーザ光を得ることができるため注目されている。

【0003】以下、図10を参照して従来のダブルヘテロ構造の横モード制御型の赤色領域に発振波長を有する半導体レーザについて説明する。この半導体レーザは、図10に示すように、n-GaAs基板1上にn-GaAsバッファ層2、n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}Pクラッド層3、Ga_{0.51}In_{0.49}P活性層4、p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}Pクラッド層5、p-Ga_{0.51}In_{0.49}P層6、n-GaAs電流ブロック層13、p-GaAsキャップ層9をこの順に備えている。そのキャップ層9上にはp側電極10が、また基板1の裏面にはn側電極11が形成されている。

【0004】この半導体レーザでは、有機金属気相成長法(MOVPE法)などの結晶成長技術が用いられる。これらの結晶成長技術を用いて、n-GaAs基板1上にn-GaAsバッファ層2、n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}Pクラッド層3、Ga_{0.51}In_{0.49}P活性層4、p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}Pクラッド

層5および p - $Ga_{0.51}In_{0.49}$ P層6を順次堆積する。

【0005】次にホトリソグラフィ技術とエッチング技術により、 p - $Ga_{0.51}In_{0.49}$ P層6と p - $(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ Pクラッド層5とを台形状にエッチングしてストライプ状リッジをクラッド層5に形成する。その後MOVPE法などを用いて n - $GaAs$ 電流ブロック層13をストライプの外部に選択的に堆積し、さらに p - $GaAs$ キャップ層9を堆積する。

【0006】このような半導体レーザの構造では、 n - $GaAs$ 電流ブロック層13により電流の狭窄を行うことができ、また p - $(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ Pクラッド層5を台形上にエッチングする際に、台形の高さ及び幅を最適化することにより、単一横モードの条件を満足する実効屈折率差を台形状のストライプの内外でつけることができ、活性層4のうち、クラッド層5のストライプ状リッジ下部に光を効果的に閉じこめることができる。ストライプの幅は典型的には約 $5\mu m$ である。

【0007】

【発明が解決しようとする課題】ところが、従来例の構造では、電流ブロック層として、活性層よりも禁制帯幅が小さい $GaAs$ を用いている。このため、この $GaAs$ 層が光の吸収層として働く。そのために、吸収による光の損失が大きく、半導体レーザの共振器内を光が導波する時の導波損失 α_1 が約 $15cm^{-1}$ と大きくなる。その結果、半導体レーザの外部微分量子効率 η_{ext} が約60%と小さくなる。また、この半導体レーザではキंक・レベルは約 $12mW$ と小さい。キंकは横モードが変化することにより生じるが、図10の構造では基本モードと高次のモードとの利得の差がさほど小さくなく、注入電流の増加により容易にモードが変化しやすくなるためである。外部微分量子効率が小さく、基本横モードの安定性が低いことから、従来例の構造では高い光出力を持つ半導体レーザが得にくい。

【0008】この発明の目的は、このような課題を解決し、高い外部微分量子効率を有する、基本横モードの安定性の高い、高出力の半導体レーザおよびその製造方法を提供することである。

【0009】

【課題を解決するための手段】本発明の半導体レーザは、半導体基板、及び、該半導体基板上に形成された積層構造であって、活性層と、該活性層を挟む一対のクラッド層と、該活性層のストライプ状所定領域に電流を注入するための電流狭窄層とを有する積層構造、を備えた半導体レーザであって、該電流狭窄層は、該活性層の該所定領域に対応する領域以外の領域に形成された第1電流ブロック層を備えており、該第1電流ブロック層は、該一対のクラッド層の屈折率よりも高い屈折率を有する半導体層であって、該活性層の禁制帯幅よりも広い禁制帯幅を有しており、そのことにより、上記目的が達成さ

れる。

【0010】ある実施例では、前記一対のクラッド層のうち、前記活性層よりも上方に位置するクラッド層は、該半導体レーザの共振器方向に沿って延びるストライプ状リッジを有しており、前記第1電流ブロック層は、該ストライプ状リッジを有する該クラッド層上において、該ストライプ状リッジ以外の領域を覆っている。

【0011】ある実施例では、前記電流狭窄層は、前記第1電流ブロック層上に設けられた第2電流ブロック層を更に備えており、該第2電流ブロック層は、前記活性層の禁制帯幅よりも広い禁制帯幅を有している半導体層である。

【0012】ある実施例では、前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、台形である。

【0013】ある実施例では、前記共振器方向に垂直な面に関する前記ストライプ状リッジの断面が、長方形である。

【0014】ある実施例では、前記半導体基板は、 $GaAs$ から形成されており、前記活性層は、 $GaInP$ から形成されており、前記第1及び第2電流ブロック層、ならびに前記一対のクラッド層は、 $AlGaInP$ から形成されている。

【0015】前記一対のクラッド層のうちの一方は、前記第1電流ブロック層を挟みこむ第1層部分及び第2層部分を有していてもよい。

【0016】ある実施例では、前記半導体基板は $GaAs$ から形成されており、前記活性層は $InGaAs$ 層を含んでおり、前記一対のクラッド層は $GaInP$ から形成されており、前記第1半導体層は $GaAs$ から形成されている。

【0017】前記活性層は、多重量子井戸構造を有していてもよい。本発明の半導体レーザの製造方法は、半導体基板上に積層構造を形成する工程を包含する半導体レーザを製造する方法であって、該工程は、第1クラッド層を形成する工程と、該第1クラッド層上に活性層を形成する工程と、該活性層上に第2クラッド層となる膜を形成する工程と、該膜の一部を選択的にエッチングすることにより、該半導体レーザの共振器方向に延びるストライプ状リッジ部を該膜に形成して、それによって第2クラッド層を形成する工程と、該第2クラッド層のうち該ストライプ状リッジ部以外の部分の上に、該第2クラッド層の屈折率よりも高い屈折率を有し、かつ、該活性層の禁制帯幅よりも広い禁制帯幅を有している第1半導体層を形成する工程と、該第1半導体層上に、該活性層の禁制帯幅よりも広い禁制帯幅を有している第2半導体層を形成する工程と、を包含しており、そのことにより上記目的が達成される。

【0018】

【作用】本発明の電流狭窄層は、活性層のストライプ状

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所定領域に対応する領域以外の領域に形成された第1電流ブロック層を備えている。この第1電流ブロック層は、一対のクラッド層の屈折率よりも高い屈折率を有し、かつ、該活性層の禁制帯幅よりも広い禁制帯幅を有している。

【0019】第1電流ブロック層は、電流が活性層に流れ込むことを阻止する機能を有する。このため、第1電流ブロック層が存在しない領域に対応する活性層の所定領域にのみ、電流が選択的に注入される。その結果、活性層のストライプ状所定領域においてのみレーザ光が発生する。このレーザ光の一部は、活性層から上下方向にもれ、クラッド層及び第1電流ブロック層に達する。第1電流ブロック層は、活性層の屈折率よりも高い屈折率を有しているため、レーザ光は、ストライプ状の所定領域から横方向へ漏れる。この理由は、一般に、光は屈折率の高い領域に集まるからである。

【0020】基本水平横モードにて発振するレーザ光と、高次の水平横モードにて発振するレーザ光とを比較して場合、高次の水平横モードにて発振するレーザ光の方は、横方向により広く分布している。このため、本発明の半導体レーザにおいては、高次の水平横モードにて発振するレーザ光の方が、基本水平横モードにて発振するレーザ光よりも、ストライプ状の所定領域から横方向へ漏れる程度が強い。このため、高次の水平横モードにて発振するレーザ光は発散し、レーザ発振に寄与しなくなる。言い替えると、第1電流ブロック層の存在によって、高次の水平横モードにて発振するレーザ光は、基本水平横モードにて発振するレーザ光に比較して、より高い閾値利得を有することとなる。その結果、基本水平横モードにて発振するレーザ光のみを選択的に得ることができる。

【0021】また、第1電流ブロック層が活性層の禁制帯幅よりも広い禁制帯幅を有しているため、活性層で発生したレーザ光は第1電流ブロック層に吸収されない。このため、従来の半導体レーザに比較して、レーザ光の伝播損失が低減される。

【0022】以上説明したように、本発明の半導体レーザは、基本水平横モードのレーザ光を低い伝播損失にて発振させることができる。

【0023】

【実施例】（実施例1）以下、この発明の実施例を図面を参照しながら説明する。

【0024】図1にこの発明の一実施例の横モード制御型の赤色半導体レーザの断面図を示す。

【0025】この半導体レーザは、図1に示すように、例えばn-GaAs基板1上にn-GaAsバッファ層2を介してGa_{0.53}In_{0.47}P活性層4（厚さ600Å）をn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}Pクラッド層3およびp-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}Pクラッド層5で挟むダブルヘテロ構造を有している。

p-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}Pクラッド層5の上部には、p-Ga_{0.53}In_{0.47}P層6（厚さ1000Å）を有し、p-Ga_{0.53}In_{0.47}P層6およびp-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}Pクラッド層5の一部は、台形状のストライプ状リッジに加工されている。クラッド層5においてストライプ状リッジ部分の厚さは1.3μm、ストライプ状リッジ部分以外の部分の厚さは0.25μmである。

【0026】ストライプ状リッジの両脇のp-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}Pクラッド層5の上には、700Åのn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層7と0.7μmのn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層8が堆積されている。さらに、p-Ga_{0.53}In_{0.47}P層6およびn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層8の上部には、p-GaAsキャップ層9を有している。

【0027】上記ストライプ状リッジの幅は基本横モードと高次のモードとの利得の差を大きくとれるような幅になっており、その幅は約7μmがよい。7μmよりも極端に細い場合、例えば約2μmの場合には、ストライプ外への光の漏洩が大きくなりすぎて、レーザ発振に寄与しない光が増加して、しきい値電流の上昇や、損失が大きくなって外部微分量子効率の低下をもたらす。また、ストライプ幅が大きくなりすぎると、基本横モードと高次のモードとの利得の差が小さくなったり、Ga_{0.53}In_{0.47}P活性層4へのキャリアの注入の不均一が水平方向で生じ、キンク・レベルの低下が発生して、実用に耐えない。

【0028】また本実施例ではストライプ状リッジの断面形状は台形であるが、この断面形状は長方形であってもよい。その場合、リッジの側面上には層7および8を形成しないことが望ましい。

【0029】この半導体レーザの各層の構成によって決まる水平方向の実効屈折率を図2に示す。ストライプ状リッジの内部の実効屈折率は3.307、ストライプ状リッジの外部の実効屈折率は3.329であり、外部の方が0.022高い。この実効屈折率差は700Åのn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層7と0.7μmのn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層8によってもたらされている。この実効屈折率差のために基本横モードと高次のモードとの間に大きな利得の差が生じる。このため、注入電流の量を大きくしてもキンクが発生しにくいので、キンクの無い状態で高い光出力を得ることができる。

【0030】ここでn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層7とn-(Al_{0.7}Ga_{0.3})_{0.53}In_{0.47}P層8によってもたらされた実効屈折率差のために、基本モードと高次モードとの間に大きな利得の差が生じていることを図11に示す。図11は、横軸にストライプ幅、縦軸にしきい値利得g_{th}をとったものである。この図に基本モード(m=0)と、高次モードとして1次モード

($m=1$) とのしきい値利得の差を (a) 本発明、
(b) 従来例のそれぞれについて記載した。この図11
からわかるように、(b) の従来例のレーザは、基本モ
ードと1次モードとのしきい値利得の差が小さく1次モ
ードのような高次モードが生じやすい。これに対して本
発明のレーザ (b) は、基本モードと1次モードとのし
きい値利得の差が大きく、1次モードのような高次モ
ードは生じにくい。

【0031】図14は、本発明の半導体レーザについ
て、駆動電流 (CURRENT) と光出力 (OUTPUT
POWER) との関係を示している。このグラフに
示されているデータは、出射端面が反射率6%の膜によ
ってコーティングされ、他の端面が反射率83%の膜に
よってコーティングされた半導体レーザについて得られ
た。半導体レーザの共振器長は500 μ mである。光出力
が約65mWを越えるまで、光出力は駆動電流の増加に
従って直線的に増加しているが、光出力が約65mWを
越えた後、光出力の増加の程度は一時的に低下する。前
述したように、グラフにおいて、そのような部分を「キ
ンク」という。キンクが発生するのは、光出力があるレ
ベル以下にあるとき、基本モード ($m=1$) にあるレー
ザ光だけが発振していたのが、光出力がそのレベル
(「キンクレベル」という) を越えると、基本モード以
外のモード (高次のモード: $m \geq 2$) にあるレーザ光と
基本モードにあるレーザ光とが混在しはじめるためであ
る。キンクレベルが高い半導体レーザほど、基本モード
にあるレーザ光を高い光出力にて安定して供給すること
ができる。基本モード ($m=1$) にあるレーザ光につい
ての閾値利得と他のモード ($m \geq 2$) にあるレーザ光に
ついての閾値利得との差が大きいほど、キンクレベルは
高くなる。

【0032】図15は、図1に示す構造を有する本発明
の半導体レーザについて、クラッド層4のストライブリ
ッジの幅と、キンクの発生する光出力のレベルとの関係
を示すグラフである。

【0033】測定のために使用した半導体レーザの共振
器長はいずれも350 μ mで、各半導体レーザの両端面
には反射膜等はコーティングされていない。図15から
わかるように、本発明の半導体レーザは、従来の半導体
レーザに比較して、キンクレベルが高い。このことは、
本発明の半導体レーザにおいて、基本モード ($m=1$)
の閾値利得と他のモード ($m \geq 2$) の閾値利得との差
が、従来の半導体レーザにおけるよりも大きいことを示
している。

【0034】また、 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7と
 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層8とは、p側電極10から流れる電流をブロックし、ク
ラッド層5のストライブリッジ内に電流を狭窄し、そ
れによって活性層4の所定の領域に電流を注入する働き
も具備している。

【0035】本発明では、台形状のストライブの内外に
屈折率差を設ける目的で、700Åの $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7と0.7 μ mの $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層8の2種類の半導体層を
用いている。1層目の半導体層、すなわち $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7の屈折率は、 $p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ Pクラッド層5の屈折率より
大きい。2層目にはクラッド層とほぼ屈折率の等しい
 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層8を用いている。光は活性層4の近傍の材料のみの屈折率の影響を受
ける。ストライブの外部で安定な実効屈折率を得ること
ができる。所望のストライブ内外での実効屈折率差は、
 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7の厚さを変
化させることで容易に得られる。すなわち、 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7が厚くなると実効屈折
率差は大きくなり、薄くなると小さくなる。そのスト
ライブ内外での屈折率差は、 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7の厚みの調整により、0.01~0.05の範囲
で制御される。

【0036】また、ここでは第1層目のAl組成を0.2
としたが、このAl組成を変化させても実効屈折率差
を変化させることができる。すなわち、Al組成が小さ
くなると実効屈折率差は大きくなり、Al組成が大き
くなると実効屈折率差は小さくなる。

【0037】1種類のための半導体層で同様の実効屈折率
差をつけるためには、屈折率が $p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ Pクラッド層5のそれより高く、かつ非常
に近い材料、例えば、 $n-(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}$ P層を組成の揺らぎが無く均一に、しかも厚く、
例えば1 μ m以上堆積する必要がある。この場合、 $n-(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}$ P層の中へ光が深く
もれるため、光は活性層4から遠く離れた場所での屈折
率の影響を受ける。また $n-(Al_{0.55}Ga_{0.45})_{0.51}In_{0.49}$ P層の組成すなわち屈折率が、設定値からずれ
ると、ストライブの内外での実効屈折率がずれたりす
る。またその厚さが薄かったら、 $Ga_{0.51}In_{0.49}$ P活
性層4で生じた光がp-GaAsキャップ層9によって
吸収されて、光エネルギーの損失が生じる。したがっ
て、半導体レーザを作製する時の安定性、再現性が低
くなる恐れが生じる。所望の実効屈折率差を正確に、再
現性よく作るためには2種類以上の半導体層を設けるこ
とが好ましい。

【0038】この半導体レーザの光出力と半導体レーザ
に注入した電流の関係を図3に示す。この半導体レーザ
では約30mWまでキンクが無い状態で光出力を得ること
ができる。また、この半導体レーザの外部微分量子効
率 η_{ext} は85%と高い。それは、水平方向の実効屈折率
差をつけるために、 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層7と
 $n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}$ P層8を用いているためである。この2層の禁制帯幅はGa

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【図9】本発明の半導体レーザの製造工程を表す第5の工程順断面図

【図10】従来例の赤色半導体レーザの断面図

【図11】本発明と従来例の基本モードと1次モードのしきい値利得の差を説明する図

【図12】本発明の半導体レーザの遠視野像を示す図

【図13】本発明の半導体レーザの各層に水平な方向の遠視野像を示す図

【図14】本発明の半導体レーザの特性を示す図で、出射端面に反射率6%のコーティング膜を、他の端面に83%のコーティング膜を設けた半導体レーザの駆動電流と光出力の関係を示す図

【図15】本発明の半導体レーザについて、ストライプ幅とキंकを発生する光出力の関係を示す図

【図16】本発明の別の実施例の横モード制御型の半導体レーザの断面図

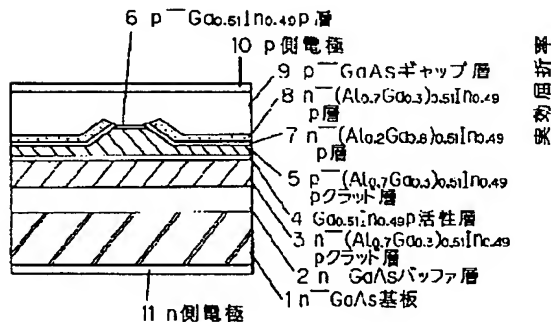
【符号の説明】

- 1 n-GaAs基板
- 2 n-GaAsバッファ層
- 3 n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}Pクラッド層
- 4 Ga_{0.51}In_{0.49}P活性層
- 5 p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}Pクラッド層
- 6 p-Ga_{0.51}In_{0.49}P層
- 7 n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P層
- 8 n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P層
- 9 p-GaAsキャップ層
- 10 p側電極
- 11 n側電極

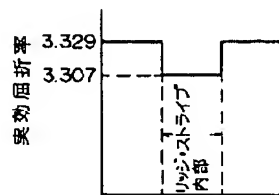
*

- *7 n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P層
- 8 n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P層
- 9 p-GaAsキャップ層
- 10 p側電極
- 11 n側電極
- 12 SiO₂
- 13 n-GaAs電流ブロック層
- 61 n-GaAs基板
- 62 n-Ga_{0.51}In_{0.49}Pクラッド層
- 63 GaAs光閉じ込め層
- 64 歪量子井戸活性層
- 64a In_{0.2}Ga_{0.8}Asウエル層
- 64b GaAsバリア層
- 64c In_{0.2}Ga_{0.8}Asウエル層
- 65 GaAs光閉じ込め層
- 66 p-Ga_{0.51}In_{0.49}Pクラッド層
- 66a 光閉じ込め層に接する第1層部
- 66b p-GaAsキャップ層68に接する第2層部
- 67 n-GaAs電流ブロック層
- 68 p-GaAsキャップ層
- 69 p側電極
- 70 n側電極

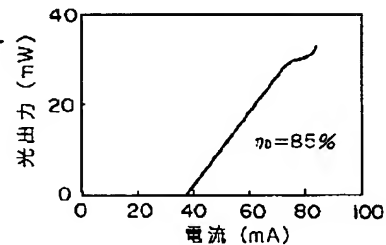
【図1】



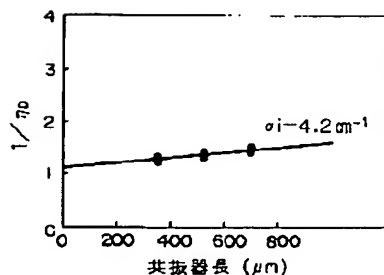
【図2】



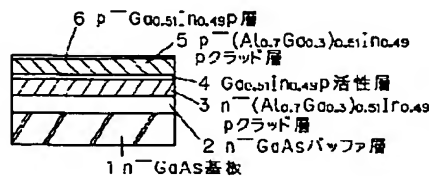
【図3】



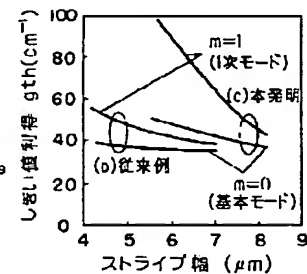
【図4】



【図5】



【図11】



$\text{In}_{0.4}\text{Ga}_{0.6}\text{As}_{0.99}\text{In}_{0.01}\text{P}$ 光閉じ込め層 (厚さ 10 nm) によって、挟まれる。

【0053】(実施例2) 図16を参照して、本発明による他の半導体レーザを説明する。

【0054】この半導体レーザは、 $n\text{-GaAs}$ 基板61、及び $n\text{-GaAs}$ 基板61上に形成された積層構造を有している。積層構造は、 $n\text{-GaAs}$ 基板61に近い側から順番に、 $n\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第1クラッド層 (厚さ: 1.5 μm) 62、 GaAs 第1光閉じ込め層 (厚さ: 0.01 μm) 63、歪量子井戸活性層64、 GaAs 第2光閉じ込め層 (厚さ: 0.01 μm) 65、 $p\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第2クラッド層66、 $n\text{-GaAs}$ 電流ブロック層 (厚さ: 0.15 μm) 67、 $p\text{-GaAs}$ キャップ層 (厚さ: 3 μm) 68を含んでいる。積層構造の $p\text{-GaAs}$ キャップ層68上には、 p 側電極69が設けられており、 $n\text{-GaAs}$ 基板61の裏面には、 n 側電極70が設けられている。

【0055】歪量子井戸活性層64は、 $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ 第1ウェル層 (厚さ: 7 nm) 64a、 GaAs バリア層 (厚さ: 10 nm) 64b及び $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$ 第2ウェル層 (厚さ: 7 nm) 64cが形成する量子井戸構造を有している。

【0056】 $p\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第2クラッド層66は、光閉じ込め層に接する第1層部分 (厚さ: 0.2 μm) 66aと、 $p\text{-GaAs}$ キャップ層68に接する第2層部分 (厚さ: 1.5 μm) 66bとに分かれている。 $p\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第2クラッド層66の第1層部分66aと第2層部分66bとの間に、 $n\text{-GaAs}$ 電流ブロック層67が位置している。

【0057】 $n\text{-GaAs}$ 電流ブロック層67は、歪量子井戸活性層64のストライプ状の所定領域 (電流注入領域) に対応する領域以外の領域に形成されている。言い替えると、 $n\text{-GaAs}$ 電流ブロック層67は、歪量子井戸活性層64の電流注入領域に対応する領域にストライプ状の開口部を有している。開口部の幅 W が電流注入領域の幅を規定している。この幅 w は典型的には6 μm であるが、約3 μm から約8 μm の範囲において種々の値が選択され得る。 $n\text{-GaAs}$ 電流ブロック層64は、 $p\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第2クラッド層66の屈折率よりも高い屈折率を有し、かつ、活性層64の禁制帯幅よりも広い禁制帯幅を有している。

【0058】 $p\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第2クラッド層66の第1層部分66aの厚さ h 、及び $n\text{-GaAs}$ 電流ブロック層67の厚さ d を調整することにより、ストライプ状電流注入領域の内外での実効屈折率差を制御することができる。 $p\text{-Ga}_{0.99}\text{In}_{0.01}\text{P}$ 第2クラッド層66の第1層部分66aの厚さは、約0.05 μm から約0.5 μm の範囲において選択され得、 $n\text{-GaAs}$ 電流ブロック層67の厚さは、約0.02 μm から約0.5 μm の範囲内で選択され得る。

【0059】本実施例の半導体レーザにおいても、前述した構造を有する本発明の半導体レーザと同様の効果が得られる。

【0060】上記クラッド層としては、 $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ($0.2 \leq x \leq 0.7$) 層または ($\text{Al}_x\text{Ga}_{1-x}$) $\text{In}_{0.4}\text{P}$ ($0 \leq x \leq 1$) 層を用いてもよい。 $(\text{Al}_x\text{Ga}_{1-x})\text{In}_{0.4}\text{P}$ ($0 \leq x \leq 1$) 層をクラッド層に使用した場合、活性層とクラッド層との間のヘテロ障壁の高さを、本実施例における高さよりも高くすることが可能となる。このため、そのようなクラッド層を採用することにより、より高温で安定に動作し得る半導体レーザが提供される。

【0061】

【発明の効果】本発明の半導体レーザによれば、

(1) 半導体レーザのクラッド層のストライプの外部に、上記クラッド層より屈折率が高く、かつ活性層の禁制帯幅よりも広い半導体層を少なくとも具備するために、吸収による光の損失が小さいことから導波損失を小さくでき、外部微分量子効率が高く、また基本横モードの安定性の高い高出力の半導体レーザを得ることができる。

【0062】本発明の半導体レーザの製造方法によれば、

(2) 半導体基板上に第1クラッド層、活性層、第2クラッド層を順次積層する工程と、第2クラッド層の一部を台形状のストライプに加工する工程と、該ストライプの外部の第2クラッド層上に、電流の注入を阻止するために少なくとも2種類以上の半導体層を積層する工程を有し、前記2種類以上の半導体層が異なる屈折率を有することから、光の導波損失を小さくすることができ、外部微分量子効率が高く、また基本横モードの安定性の高い高出力の半導体レーザを容易に再現性よく作製することができる。

【図面の簡単な説明】

【図1】本発明の実施例の横モード制御型の赤色半導体レーザの断面図

【図2】本発明の実施例の半導体レーザの層に水平方向の実効屈折率を表す図

【図3】本発明の実施例の半導体レーザの光出力と電流の関係を示す図

【図4】本発明の効果を説明するための図で、外部微分量子効率の逆数 $1/\eta_o$ と共振器長の関係を示す図

【図5】本発明の半導体レーザの製造工程を表す第1の工程順断面図

【図6】本発明の半導体レーザの製造工程を表す第2の工程順断面図

【図7】本発明の半導体レーザの製造工程を表す第3の工程順断面図

【図8】本発明の半導体レーザの製造工程を表す第4の工程順断面図

$0.51 \text{ In}_{0.49}$ P 活性層 4 のそれよりも大きい。そのために、 $\text{Ga}_{0.51} \text{ In}_{0.49}$ P 活性層 4 で発生した光は吸収されることがなく、したがって導波損失 α_1 は小さく、その結果高い外部微分量子効率を得ることができる。図 4 は導波損失を調べるための実験結果で、外部微分量子効率の逆数 $1/\eta_0$ と半導体レーザの共振器長の関係を示す図である。 $1/\eta_0$ と共振器長の間には比例関係があり、この傾きから導波損失は 4.2 cm^{-1} と導出できる。従来例の半導体レーザの導波損失は約 15 cm^{-1} であるから、本発明の半導体レーザは $1/3 \sim 1/4$ の値をとることになる。したがって、本発明の半導体レーザの外部微分量子効率が高いことが説明できる。

【0039】つぎに本発明の半導体レーザが良好な特性をもつことの説明として、本発明の遠視野像を測定した結果を図 12 に示す。

【0040】(a) は半導体レーザの各層に水平な方向の角度に対する出力光の強度分布であり、(b) は各層に垂直な方向の角度に対する出力光の強度分布を示している。

【0041】(a) の各層に水平方向の遠視野像のメインのピークの横に小さなサイド・ロブが見られる。このサイド・ロブは本発明の半導体レーザの特徴であるが、この半導体レーザが高次モードで発振しているということではなく、リッジ・ストライプの外にもれた光のためによる。

【0042】このように、本発明の半導体レーザは、その遠視野像からともに基本モードで発振していることがわかる。

【0043】なお、図 12 に示したメインのピークとサイド・ロブをわかりやすく説明したのが図 13 である。半導体レーザの各層に水平な方向の光の強度分布である。

【0044】以上述べたように、高い基本モード安定性と高い外部微分量子効率から、高出力の半導体レーザを得ることができる。

【0045】つぎに、この半導体レーザの作製方法を図 5 から図 9 を用いて説明する。まず、MOVPE 法などの結晶成長方法を用いて、 $n\text{-GaAs}$ 基板 1 上に $n\text{-GaAs}$ バッファ層 2、 $n\text{-(Al}_{0.7}\text{Ga}_{0.3})_{0.51}\text{In}_{0.49}$ P クラッド層 3、 $\text{Ga}_{0.51}\text{In}_{0.49}$ P 活性層 4、 $p\text{-(Al}_{0.7}\text{Ga}_{0.3})_{0.51}\text{In}_{0.49}$ P クラッド層 5、 $p\text{-Ga}_{0.51}\text{In}_{0.49}$ P 層 6 をエピタキシャル成長させる (図 5)。 SiO_2 12 を $p\text{-Ga}_{0.51}\text{In}_{0.49}$ P 層 6 上に堆積させた後、ホトリソグラフィ技術とエッチング技術を用いて、 SiO_2 12 と $p\text{-Ga}_{0.51}\text{In}_{0.49}$ P 層 6 と $p\text{-(Al}_{0.7}\text{Ga}_{0.3})_{0.51}\text{In}_{0.49}$ P クラッド層 5 の一部を台形状のストライプに加工する (図 6)。台形状に加工した後、MOVPE 法の選択成長技術を用いて、電流ブロック層として $n\text{-(Al}_{0.2}\text{Ga}_{0.8})_{0.51}\text{In}_{0.49}$ P 層 7 と $n\text{-(Al}_{0.7}\text{Ga}_{0.3})$

$0.51 \text{ In}_{0.49}$ P 層 8 を SiO_2 12 上に堆積させることなく、ストライプの両脇の $p\text{-(Al}_{0.7}\text{Ga}_{0.3})_{0.51}\text{In}_{0.49}$ P クラッド層 5 上に結晶成長させる (図 7)。その後、 SiO_2 12 を除去し、 $p\text{-GaAs}$ キャップ層 9 を結晶成長させる (図 8)。最後に $p\text{-GaAs}$ コンタクト層 9 上に Cr/Pt/Au を堆積して p 側電極 10 とし、 $n\text{-GaAs}$ 基板 1 上に Au/Ge/Ni を堆積して n 側電極 11 とする (図 9)。

【0046】このような製造方法により、図 1 に示すような横モード制御型の赤色半導体レーザを作製することができる。

【0047】なお、本実施例では台形状のストライプの内外に実効屈折率差を設けるために、2 種類の半導体層を用いて説明したが、3 種類以上用いても実効屈折率を作ることができる。

【0048】上記実施例では台形状のストライプの内部の実効屈折率をストライプの外部のそれよりも、0.022 低くしてあるが、この実効屈折率差は 0.01 から 0.05 の範囲であれば、本発明の効果は大きい。ただし、実効屈折率差が変われば、それに合わせて、台形状のストライプ幅も変化させなくてはならない。

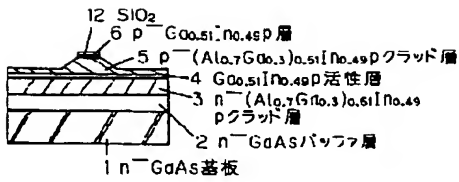
【0049】なおクラッド層 5 のストライプ状リッジ外部の厚さ h 、および層 7 の厚さを変化させることによりストライプ状リッジの外の部分の実効屈折率を制御することができる。 h の厚さの範囲は $0.05 \sim 0.5 \mu\text{m}$ 、層 7 の厚さの範囲は $0.02 \sim 0.5 \mu\text{m}$ 、層 8 の厚さの範囲は $0.3 \sim 1 \mu\text{m}$ が好ましい。

【0050】上記実施例では半導体レーザを構成する材料を指定したが、クラッド層が $(\text{Al}_z\text{Ga}_{1-z})_{0.51}\text{In}_{0.49}\text{P}$ 、活性層が $(\text{Al}_z\text{Ga}_{1-z})_{0.51}\text{In}_{0.49}\text{P}$ (ここで、 $0 \leq z \leq 1$) の場合でも、外部微分量子効率が大きく、横モード安定性の高い、高出力の半導体レーザを容易に作製することができる。

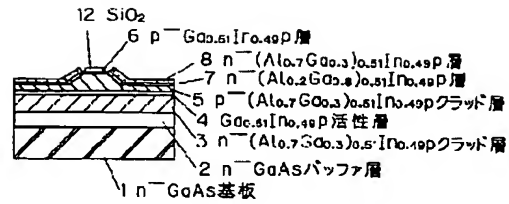
【0051】また、上記実施例では材料に AlGaInP を用いた半導体レーザについて説明したが、他の材料でも本発明の効果は大きいことは言うまでもない。 III-V 族の半導体レーザのみならず、 III-VI 族の材料から成る半導体レーザでもこの発明の効果は大きい。

【0052】上記実施例の活性層は、 AlGaInP 半導体の単層によって形成されているが、多重量子井戸構造を有する活性層が使用され得る。そのような活性層としては、例えば、 $\text{Ga}_{0.44}\text{In}_{0.56}\text{P}$ ウェル層 (厚さ 8 nm)、 $(\text{Al}_{0.45}\text{Ga}_{0.55})_{0.51}\text{In}_{0.49}\text{P}$ バリア層 (厚さ 5 nm)、 $\text{Ga}_{0.44}\text{In}_{0.56}\text{P}$ ウェル層 (厚さ 8 nm)、 $(\text{Al}_{0.45}\text{Ga}_{0.55})_{0.51}\text{In}_{0.49}\text{P}$ バリア層 (厚さ 5 nm)、及び、 $\text{Ga}_{0.44}\text{In}_{0.56}\text{P}$ ウェル層 (厚さ 8 nm) 含んだ活性層を使用してもよい。このような活性層は、3 つのウェル層に 0.5% の圧縮歪が生じているため、歪多重量子井戸活性層と呼ばれる。この多重量子井戸活性層は、クラッド層に接する一対の (A

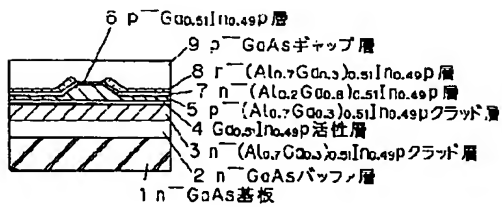
【図6】



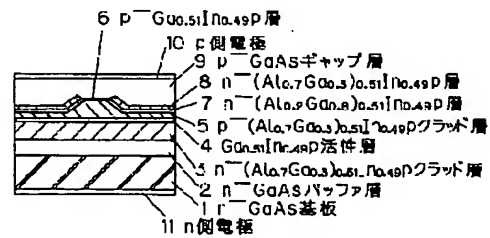
【図7】



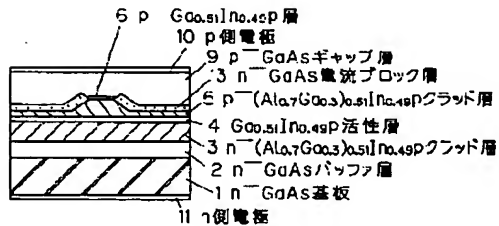
【図8】



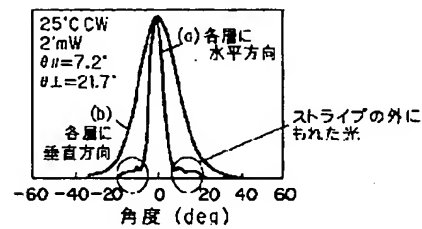
【図9】



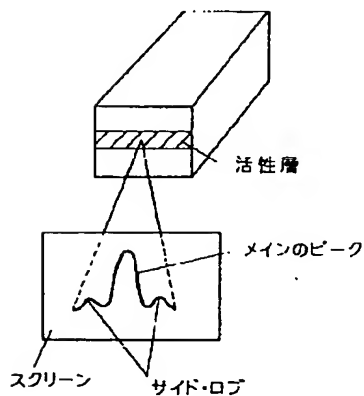
【図10】



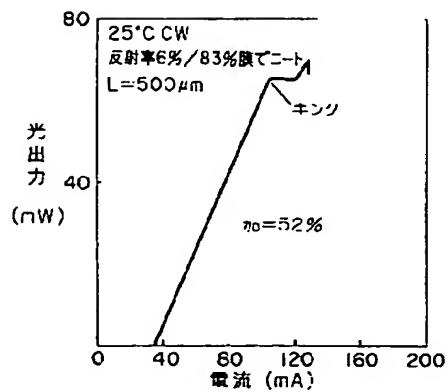
【図12】



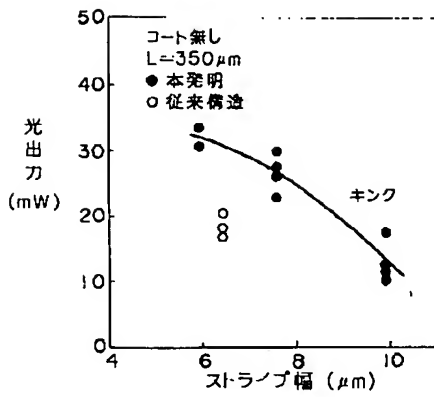
【図13】



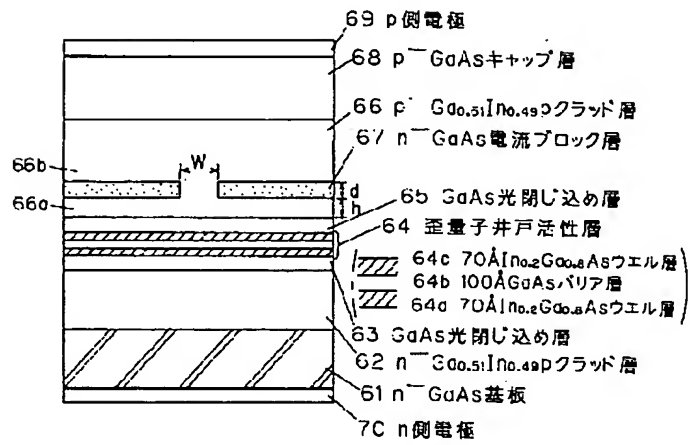
【図14】



【図15】



【図16】



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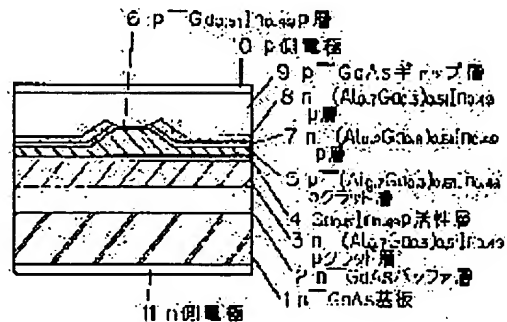
JP

(54) SEMICONDUCTOR LASER AND FABRICATION THEREOF

(57)Abstract:

PURPOSE: To provide a high output semiconductor laser having oscillation wavelength in visible light region in which differential quantum efficiency is enhanced while enhancing the stability of transverse mode.

CONSTITUTION: A p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49} clad layer 5 of semiconductor laser is partially formed into a trapezoidal stripe. An n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and an n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 are deposited on a p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 on the outside of the stripe. Effective refractive index in the trapezoidal stripe is set lower by 0.02 than that on the outside of the stripe.



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CLAIMS

[Claim(s)]

[Claim 1] It is the laminated structure formed on the semiconductor substrate and this semiconductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the clad layer of the couple which sandwiches this barrier layer, and a current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. this current constriction layer It has the 1st-current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. this 1st-current block layer Semiconductor laser which is the semiconductor layer which has a refractive index higher than the refractive index of the clad layer of this couple, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[Claim 2] It is the semiconductor laser to which the clad layer which is semiconductor laser according to claim 1, and is located among the clad layers of the aforementioned couple more nearly up than the aforementioned barrier layer has the stripe-like ridge prolonged along the orientation of a resonator of this semiconductor laser, and the aforementioned 1st-current block layer has covered fields other than this stripe-like ridge on this clad layer that has this stripe-like ridge.

[Claim 3] The aforementioned current constriction layer is semiconductor laser according to claim 2 which is the semiconductor layer which is further equipped with the 2nd-current block layer prepared on the aforementioned 1st-current block layer, and has the forbidden-band width of face with this 2nd-current block layer larger than the forbidden-band width of face of the aforementioned barrier layer.

[Claim 4] Semiconductor laser according to claim 3 whose cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a trapezoid.

[Claim 5] Semiconductor laser according to claim 3 whose cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a rectangle.

[Claim 6] It is the semiconductor laser according to claim 3 in which the aforementioned semiconductor substrate is formed in from GaAs, the aforementioned barrier layer is formed in from GaInP, and the above 1st, the 2nd-current block layer, and the clad layer of the aforementioned couple are formed from AlGaInP.

[Claim 7] The aforementioned barrier layer is semiconductor laser according to claim 1 which has multiplex quantum well structure.

[Claim 8] One side of the clad layers of the aforementioned couple is semiconductor laser according to claim 1 which has the 1st layer fraction and the 2nd layer fraction which are crowded on both sides of the aforementioned 1st-current block layer.

[Claim 9] It is the semiconductor laser according to claim 8 in which the aforementioned semiconductor substrate is formed in from GaAs, the aforementioned barrier layer contains InGaAs layer in, the clad layer of the aforementioned couple is formed in from GaInP, and the aforementioned 1st semiconductor layer is formed from GaAs.

[Claim 10] The aforementioned barrier layer is semiconductor laser according to claim 8 which has multiplex quantum well structure.

[Claim 11] It is the technique of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semiconductor substrate. this process Furthermore, the process which forms the 1st clad layer, the process which forms a barrier layer on this 1st clad layer, the process which forms the layer used as the 2nd clad layer on this barrier layer, and a part of this layer by etching alternatively The stripe-like ridge section prolonged in the orientation of a resonator of this semiconductor laser is formed in this layer. Among the process which forms the 2nd clad layer by it, and this 2nd clad layer, on fractions other than this stripe-like ridge section The process which forms the 1st semiconductor layer which has a refractive index higher than the refractive index of this 2nd clad layer, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The manufacture technique of the semiconductor laser which includes the process which forms the 2nd semiconductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semiconductor layer.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001] [Field of the Invention] It is related with the semiconductor laser and its manufacture technique of the high power which luminous efficiency of this invention was [high power] high and was excellent in the stability of the basic transverse mode.

[0002] [Description of the Prior Art] The semiconductor laser which produces a laser oscillation and emits light in a light field has the intended use of the light sources for optical information processings, such as a laser beam printer and an optical disk, etc., and is increasing the importance recently. Especially, grid matching of the material of $0.5(\text{Al}_x\text{Ga}_{1-x})\text{In}_{0.5}\text{P}$ system is carried out to GaAs which is a good substrate material, and since it can obtain the laser beam which has the arbitrary wavelength within the limits of 0.68 to 0.56 micrometers by changing composition x , it attracts attention.

[0003] Hereafter, the semiconductor laser which has oscillation wavelength with reference to drawing 10 to the transverse-mode control type red field of the conventional double hetero structure is explained. This semiconductor laser is equipped with the n-GaAs buffer layer 2, the n-(aluminum $_{0.7}\text{Ga}_{0.3}$) $_{0.51}\text{In}_{0.49}\text{P}$ clad layer 3, Ga $_{0.51}\text{In}_{0.49}\text{P}$ barrier layer 4, the p- $_{0.51}(\text{aluminum}_{0.7}\text{Ga}_{0.3})\text{In}_{0.49}\text{P}$ clad layer 5, p-Ga $_{0.51}\text{In}_{0.49}\text{P}$ layer 6, the n-GaAs current block layer 13, and the p-GaAs cap layer 9 on the n-GaAs substrate 1 at this order, as shown in drawing 10. The p lateral electrode 10 is formed on the cap layer 9, and the n lateral electrode 11 is formed in the rear face of a substrate 1.

[0004] In this semiconductor laser, crystal-growth techniques, such as an organic-metal vapor growth (the MOVPE method), are used. The n-GaAs buffer layer 2, the n-(aluminum $_{0.7}\text{Ga}_{0.3}$) $_{0.51}\text{In}_{0.49}\text{P}$ clad layer 3, Ga $_{0.51}\text{In}_{0.49}\text{P}$ barrier layer 4, the p-(aluminum $_{0.7}\text{Ga}_{0.3}$) $_{0.51}\text{In}_{0.49}\text{P}$ clad layer 5, and p-Ga $_{0.51}\text{In}_{0.49}\text{P}$ layer 6 are deposited one by one on the n-GaAs substrate 1 using such crystal-growth techniques.

[0005] Next, with photolithography technique and etching technique, p-Ga_{0.51}In_{0.49}P layer 6 and the p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 are etched in the shape of a trapezoid, and a stripe-like ridge is formed in the clad layer 5. The n-GaAs current block layer 13 is alternatively deposited on the exterior of a stripe after that using the MOVPE method etc., and the p-GaAs cap layer 9 is deposited further.

[0006] With such structure of semiconductor laser, the n-GaAs current block layer 13 can perform the constriction of a current. In case the p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 is etched on a trapezoid, moreover, by optimizing a trapezoid height and trapezoid width of face. The effective-refractive-index difference with which it is satisfied of the conditions of a single transverse mode can be given within and without a trapezoid-like stripe, and light can be effectively confined in the stripe-like ridge lower part of the clad layer 5 among barrier layers 4. The width of face of a stripe is about 5 micrometers typically.

[0007] [Problem(s) to be Solved by the Invention] However, with the structure of the conventional example, forbidden-band width of face uses parvus GaAs rather than the barrier layer as a current block layer. For this reason, this GaAs layer works as an absorption-of-light layer. Therefore, a loss of the light by absorption is large and waveguide loss α_{ph} in case light guides the inside of the resonator of semiconductor laser becomes large with abbreviation 15cm-1. Consequently, the external differential quantum efficiency of semiconductor laser becomes small with about 60%. Moreover, at this semiconductor laser, kink level is about 12mW and the parvus. Although a kink is produced when the transverse mode changes, with the structure of drawing 10, it is for the mode to become easy to change with the increases in an inrush current easily so greatly [the difference of the gain in a basic mode and the high order mode]. Since external differential quantum efficiency is small and the stability of the basic transverse mode is low, with the structure of the conventional example, it is hard to obtain the semiconductor laser with a high optical output.

[0008] The purpose of this invention is offering the semiconductor laser of high power with the high stability of the basic transverse mode which solves such a technical problem and has high external differential quantum efficiency, and its manufacture technique.

[0009] [Means for Solving the Problem] The semiconductor laser of this invention is the laminated structure formed on the semiconductor substrate and this semiconductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the clad layer of the couple which sandwiches this barrier layer, and a current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. this current constriction layer It has the 1st-current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. this 1st-current block layer It is the semiconductor layer which has a refractive index higher than the refractive index of the clad layer of this couple, and it has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, and the above-mentioned purpose is attained by that.

[0010] In a certain example, the clad layer located among the clad layers of the aforementioned couple more nearly up than the aforementioned barrier layer has the stripe-like ridge prolonged along the orientation of a resonator of this semiconductor laser, and the aforementioned 1st-current block layer has covered fields other than this stripe-like ridge on this clad layer that has this stripe-like ridge.

[0011] In a certain example, the aforementioned current constriction layer is further equipped with the 2nd-current block layer prepared on the aforementioned 1st-current block layer, and this 2nd-current block layer is a semiconductor layer which has forbidden-band width of face larger than the forbidden-band width of face of the aforementioned barrier layer.

[0012] In a certain example, the cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a trapezoid.

[0013] In a certain example, the cross section of the aforementioned stripe-like ridge about a field perpendicular to the aforementioned resonator orientation is a rectangle.

[0014] In a certain example, the aforementioned semiconductor substrate is formed from GaAs, the aforementioned barrier layer is formed from GaInP, and the above 1st, the 2nd-current block layer, and the clad layer of the aforementioned couple are formed from AlGaInP.

[0015] One side of the clad layers of the aforementioned couple may have the 1st layer fraction and the 2nd layer fraction which are crowded on both sides of the aforementioned 1st-current block layer.

[0016] In a certain example, the aforementioned semiconductor substrate is formed from GaAs, the aforementioned barrier layer contains InGaAs layer, the clad layer of the aforementioned couple is formed from GaInP, and the aforementioned 1st semiconductor layer is formed from GaAs.

[0017] The aforementioned barrier layer may have multiplex quantum well structure. The manufacture technique of the semiconductor laser of this invention is the technique of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semiconductor substrate. this process The process which forms the 1st clad layer, the process which forms a barrier layer on this 1st clad layer, the process which forms the layer used as the 2nd clad layer on this barrier layer, and a part of this layer by etching alternatively The stripe-like ridge section prolonged in the orientation of a resonator of this semiconductor laser is formed in this layer. Among the process which forms the 2nd clad layer by it, and this 2nd clad layer, on fractions other than this stripe-like ridge section The process which forms the 1st semiconductor layer which has a refractive index higher than the refractive index of this 2nd clad layer, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The process which forms the 2nd semiconductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semiconductor layer is included, and the above-mentioned purpose is attained by that.

[0018] [Function] The current constriction layer of this invention is equipped with the 1st-current block layer formed in fields other than the field corresponding to the stripe-like predetermined field of a barrier layer. This 1st-current block layer has a refractive index higher than the refractive index of the clad layer of a couple, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[0019] The 1st-current block layer has the function which prevents that a current flows into a barrier layer. For this reason, a current is alternatively poured only into the predetermined field of the barrier layer corresponding to the field to which the 1st-current block layer does not exist. Consequently, a laser beam occurs only in the stripe-like predetermined field of a barrier layer. A part of this laser beam leaks in the vertical orientation from a barrier layer, and it reaches a clad layer and the 1st-current block layer. Since the 1st-current block layer has the refractive index

higher than the refractive index of a barrier layer, a laser beam leaks from a predetermined stripe-like field to longitudinal direction. Generally this ground is that it gathers in the field where light of a refractive index is high.

[0020] the laser beam oscillated in the basic level transverse mode, and the laser beam oscillated in the high order level transverse mode -- comparing -- a case -- the high order level transverse mode -- oscillating -- a laser beam -- the direction is widely distributed by longitudinal direction. For this reason, in the semiconductor laser of this invention, the grade which leaks from a predetermined stripe-like field to longitudinal direction is stronger than the laser beam which the direction of the laser beam oscillated in the high order level transverse mode oscillates in the basic level transverse mode. For this reason, it emits and the laser beam oscillated in the high order level transverse mode stops contributing to a laser oscillation. In other words, the laser beam oscillated in the high order level transverse mode will have higher threshold gain by presence of the 1st-current block layer as compared with the laser beam oscillated in the basic level transverse mode. Consequently, only the laser beam oscillated in the basic level transverse mode can be obtained alternatively.

[0021] Moreover, since it has the forbidden-band width of face with the 1st-current block layer larger than the forbidden-band width of face of a barrier layer, the laser beam generated by the barrier layer is not absorbed by the 1st-current block layer. For this reason, a transmission loss of racer light is reduced as compared with the conventional semiconductor laser.

[0022] As explained above, the semiconductor laser of this invention can oscillate the laser beam of the basic level transverse mode by low transmission loss.

[0023]

[Example] (Example 1) The example of this invention is explained hereafter, referring to a drawing.

[0024] The cross section of the transverse-mode control type red semiconductor laser of one example of this invention is shown in drawing 1 .

[0025] This semiconductor laser has the double hetero structure which sandwiches Ga_{0.51}In_{0.49}P barrier layer 4 (thickness 600 ***** ** strike loam) through the n-GaAs buffer layer 2 on the n-GaAs substrate 1 in the n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 3 and the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5, as shown in drawing 1 . In the upper part of the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5, it has p-Ga_{0.51}In_{0.49}P layer 6 (1000Å in thickness), and a part of p-Ga_{0.51}In_{0.49}P layer 6 and p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 is processed into the trapezoid-like stripe-like ridge. In the clad layer 5, the thickness of fractions other than 1.3 micrometers and a stripe-like ridge fraction of the thickness of a stripe-like ridge fraction is 0.25 micrometers.

[0026] On the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 of both the sides of a stripe-like ridge, n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 of 700** and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 [0.7-micrometer] have accumulated. Furthermore, in the upper part of p-Ga_{0.51}In_{0.49}P layer 6 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8, it has the p-GaAs cap layer 9.

[0027] The width of face of the above-mentioned stripe-like ridge is the width of face which can take the large difference of the gain in the basic transverse mode and the high order mode, and the width of face has good about 7 micrometers. When extremely thinner than 7 micrometers, in

about 2 micrometers, a leakage of the light to the outside of a stripe becomes large too much, the light which does not contribute to a laser oscillation increases, elevation of a threshold current and a loss become large, and a fall of external differential quantum efficiency is brought. Moreover, if stripe width of face becomes large too much, the difference of the gain in the basic transverse mode and the high order mode becomes small, or the ununiformity of injection of the carrier to Ga_{0.51}In_{0.49}P barrier layer 4 will be horizontal, and will arise, a fall of kink level will occur, and practical use will not be borne.

[0028] Moreover, although the cross-section configuration of a stripe-like ridge is a trapezoid in this example, this cross-section configuration may be a rectangle. In this case, it is desirable not to form layers 7 and 8 on the side face of a ridge.

[0029] The horizontal effective refractive index decided by the configuration of each class of this semiconductor laser is shown in drawing 2. the effective refractive index inside a stripe-like ridge -- the effective refractive index of the exterior of 3.307 and a stripe-like ridge -- 3.329 -- it is -- external one -- 0.022 -- it is high This effective-refractive-index difference is brought by n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 of 700**, and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 [0.7-micrometer]. The difference of big gain arises between the basic transverse mode and the high order mode for this effective-refractive-index difference. For this reason, since it is hard to generate a kink even if it enlarges the amount of an inrush current, a high optical output can be obtained in the status that there is no kink.

[0030] It is shown in drawing 11 that the difference of big gain has arisen between a basic mode and the higher mode for the effective-refractive-index difference brought by n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 here. Drawing 11 is taken stripe width of face along a quadrature axis, and, as for it, the threshold gain g_{th} is taken along an axis of ordinate. The difference of the threshold gain with primary mode (m= 1) was indicated about each of (a) this invention and the (b) conventional example as a basic mode (m= 0) and higher mode to this drawing. As shown in this drawing 11, the higher mode [like / the difference of the threshold gain in a basic mode and primary mode is small, and / primary mode] it is tends to produce the laser of the conventional example of (b). On the other hand, the laser (b) of this invention has the large difference of the threshold gain in a basic mode and primary mode, and it is hard to produce the higher mode like primary mode.

[0031] Drawing 14 shows the relation between a drive current (CURRENT) and an optical output (OUTPUT POWER) about the semiconductor laser of this invention. The outgoing-radiation end face was coated with the layer of 6% of reflection factors, and the data shown in this graph were obtained about the semiconductor laser coated with other end faces with the layer of 83% of reflection factors. The cavity length of semiconductor laser is 500micro. Although the optical output is increasing linearly according to the increase in a drive current until an optical output exceeds about 65mW, after an optical output exceeds about 65mW, the grade of the increase in an optical output falls temporarily. As mentioned above, in a graph, such a fraction is called "kink." It is because the laser beam which that only the laser beam in a basic mode (m= 1) was oscillating has in the laser beam in modes (high order mode:m>=2) other than a basic mode and a basic mode when an optical output exceeds the level (it is called "kink level") begins to be intermingled that a kink occurs, when it is below in the level with an optical output. The semiconductor laser with higher kink level can stabilize for it and supply the laser beam in a basic mode in a high optical output. **** ** level becomes high so that the difference with the

threshold gain about the laser beam in the threshold gain about the laser beam in a basic mode ($m=1$) and other modes ($m \geq 2$) is large.

[0032] Drawing 15 is a graph which shows the relation between the width of face of the stripe ridge of the clad layer 4, and the level of the optical output which a kink generates about the semiconductor laser of this invention which has the structure shown in drawing 1.

[0033] Each cavity length of the semiconductor laser used for measurement is 350 micrometers, and the ends side of each semiconductor laser is not coated with the reflective layer etc. As shown in drawing 15, the semiconductor laser of this invention has high kink level as compared with the conventional semiconductor laser. This shows that the difference of the threshold gain of a basic mode ($m=1$) and the threshold gain in other modes ($m \geq 2$) is large rather than it can set to the conventional semiconductor laser in the semiconductor laser of this invention.

[0034] Moreover, n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 block the current which flows from the p lateral electrode 10, they carry out the constriction of the current into the stripe-like ridge of the clad layer 5, and also possess the work which pours a current into the predetermined field of a barrier layer 4 by it.

[0035] In this invention, n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 of 700** and two kinds of 0.7-micrometer semiconductor layers of n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 are used in order to prepare a refractive-index difference within and without a trapezoid-like stripe. The layer 1st] semiconductor layer, i.e., the refractive index of n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7, is larger than the refractive index of the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5. A clad layer and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 with an almost equal refractive index are used for two-layer scale division. Light is influenced of the refractive index of only the material near the barrier layer 4. A stable effective refractive index can be obtained in the exterior of a stripe. The effective-refractive-index difference in desired stripe inside and outside is easily acquired by changing the thickness of n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7. That is, it will become small if an effective-refractive-index difference will become large if n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 becomes thick, and it becomes thin. The refractive-index difference in the stripe inside and outside is controlled by adjustment of the thickness of n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 in 0.01-0.05.

[0036] Moreover, although the 1st-layer aluminum composition was set to 0.2 here, even if it changes this aluminum composition, an effective-refractive-index difference can be changed. That is, if an effective-refractive-index difference will become large if aluminum composition becomes small, and aluminum composition becomes large, an effective-refractive-index difference will become small.

[0037] In order to give the same effective-refractive-index difference in one kind of semiconductor layer, there is no fluctuation of composition, and moreover, it needs to be thick, for example, it is necessary to deposit uniformly, 1 micrometers or more of the materials with it, for example, n-(aluminum_{0.55}Ga_{0.45})_{0.51}In_{0.49}P layer. [a refractive index higher than that of the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 and, and] [very near] In this case, since light leaks deeply into n-(aluminum_{0.55}Ga_{0.45})_{0.51}In_{0.49}P layer, light is influenced of the refractive index in the location distant distantly [barrier layer / 4]. Moreover, if it shifts from the set point, n-(aluminum_{0.55}Ga_{0.45})_{0.51}In_{0.49}P layer composition, i.e., a refractive index, the effective refractive index in the inside and outside of a stripe will shift. Moreover, if the

thickness is thin, the light produced by Ga_{0.51}In_{0.49}P barrier layer 4 will be absorbed by the p-GaAs cap layer 9, and a loss of a light energy will arise. Therefore, a possibility that the stability when producing semiconductor laser and repeatability may become low arises. In order to make a desired effective-refractive-index difference with sufficient repeatability correctly, it is desirable to prepare two or more kinds of semiconductor layers.

[0038] The relation of the current poured into the optical output of this semiconductor laser and semiconductor laser is shown in drawing 3. At this semiconductor laser, an optical output can be obtained in the status that there is no kink to about 30mW. Moreover, external differential quantum efficiency η_D of this semiconductor laser is as high as 85%. Since it gives a horizontal effective-refractive-index difference, it is because n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 are used. This two-layer forbidden-band width of face is larger than that of Ga_{0.51}In_{0.49}P barrier layer 4. Therefore, the light generated by Ga_{0.51}In_{0.49}P barrier layer 4 is not absorbed, therefore, as a result, waveguide loss α_{wh} can obtain high external differential quantum efficiency small. Drawing 4 is an experimental result for investigating a waveguide loss, and is drawing showing the relation of the cavity length of inverse number $1/\eta_D$ of external differential quantum efficiency, and semiconductor laser. A proportionality is between $1/\eta_D$, and a cavity length, and a waveguide loss can be derived from this inclination with 4.2cm^{-1} . Since a waveguide loss of the semiconductor laser of the conventional example is abbreviation 15cm^{-1} , the semiconductor laser of this invention will take the value of $1/3 - 1/4$. Therefore, it can explain that the external differential quantum efficiency of the semiconductor laser of this invention is high.

[0039] As an explanation of the semiconductor laser of this invention having a good property next, the result which measured the far field pattern of this invention is shown in drawing 12.

[0040] (a) is the output luminous-intensity distribution to the angle of orientation level on each class of semiconductor laser, and (b) shows the output luminous-intensity distribution to the angle of orientation perpendicular to each class.

[0041] A small side lobe is seen beside the main peaks of a far field pattern horizontal to each class of (a). Although this side lobe is the characteristic feature of the semiconductor laser of this invention, it depends for the light from which this semiconductor laser is not oscillating by the higher mode, and leaked out of the ridge stripe.

[0042] Thus, it turns out that both the semiconductor laser of this invention is oscillated by the basic mode from the far field pattern.

[0043] In addition, drawing 13 explained plainly the main peaks shown in drawing 12, and the side lobe. It is a luminous-intensity distribution of orientation level on each class of semiconductor laser.

[0044] As stated above, the semiconductor laser of high power can be obtained from a high basic transverse-mode stability and high external differential quantum efficiency.

[0045] Below, from drawing 5, drawing 9 is used and the production technique of this semiconductor laser is explained. First, the n-GaAs buffer layer 2, the n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 3, Ga_{0.51}In_{0.49}P barrier layer 4, the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5, and p-Ga_{0.51}In_{0.49}P layer 6 are grown epitaxially on the n-GaAs substrate 1 using the crystal-growth technique, such as the MOVPE method, (drawing 5). After making SiO₂ deposit on p-Ga_{0.51}In_{0.49}P layer 6, a part of

SiO₂12, p-Ga_{0.51}In_{0.49}P layer 6, and p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 are processed into a trapezoid-like stripe using photolithography technique and etching technique (drawing 6). A crystal growth is carried out on the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 of both the sides of a stripe, without making n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 deposit on SiO₂12 as a current block layer using the selective-growth technique of the MOVPE method, after processing it in the shape of a trapezoid (drawing 7). Then, SiO₂12 is removed and the crystal growth of the p-GaAs cap layer 9 is carried out (drawing 8). Finally Cr/Pt/Au is deposited on the p-GaAs contact layer 9, it considers as the p lateral electrode 10, Au/germanium/nickel is deposited on the n-GaAs substrate 1, and it considers as the n lateral electrode 11 (drawing 9).

[0046] By such manufacture technique, the transverse-mode control type red semiconductor laser which is shown in drawing 1 is producible.

[0047] In addition, although two kinds of semiconductor layers were used and explained in order to establish an effective-refractive-index difference within and without a trapezoid-like stripe, even if it uses three or more kinds, an effective refraction difference can be made from this example.

[0048] the above-mentioned example -- the effective refractive index inside a trapezoid-like stripe -- it of the exterior of a stripe -- 0.022 -- although it is made low, if the domain of this effective-refractive-index difference is 0.01 to 0.05, the effect of this invention is large. However, if an effective-refractive-index difference changes, it must double with it and trapezoid-like stripe width of face must also be changed.

[0049] In addition, the effective refractive index of the fraction besides a stripe-like ridge is controllable by changing thickness h of the stripe-like ridge exterior of the clad layer 5, and the thickness of a layer 7. The domain of the thickness of 0.02-0.5 micrometers and the layer 8 has [the domain of the thickness of h / the domain of the thickness of 0.05-0.5 micrometers and the layer 7] desirable 0.3-1 micrometer.

[0050] Although the material which constitutes semiconductor laser from an above-mentioned example was specified, external differential quantum efficiency has a large clad layer also at the case of 0.51(Al_zGa_{1-z})In_{0.49}P (it is 0 ≤ z ≤ y ≤ 1 here), and 0.51(Al_yGa_{1-y})In_{0.49}P and a barrier layer can produce easily the semiconductor laser of high power with a high transverse-mode stability.

[0051] Moreover, although the above-mentioned example explained the semiconductor laser which used AlGaInP for the material, it cannot be overemphasized that other materials of the effect of this invention are large. Not only an III-V group's semiconductor laser but the semiconductor laser of this effect of the invention which consists of an II-VI group's material is large.

[0052] Although the barrier layer of the above-mentioned example is formed of the monolayer of AlGaInP semiconductor, the barrier layer which has multiplex quantum well structure may be used. As such a barrier layer, for example A Ga_{0.44}In_{0.56}P well layer (8nm in thickness), A 0.51In_{0.49}P barrier layer (5nm in thickness), (aluminum_{0.45}Ga_{0.55}) You may use a Ga_{0.44}In_{0.56}P well layer (8nm in thickness), a 0.51(aluminum_{0.45}Ga_{0.55})In_{0.49}P barrier layer (5nm in thickness), and the barrier layer included the Ga_{0.44}In_{0.56}P well layer (8nm in thickness). Since 0.5% of the compressive strain has arisen in three well layers, such a barrier

layer is called oval multiplex quantum well barrier layer. This multiplex quantum well barrier layer is sandwiched by 0.51(aluminum0.45Ga0.55) In0.49P light closing ***** (10nm in thickness) of the couple which touches a clad layer.

[0053] (Example 2) With reference to view 16 , other semiconductor laser by this invention is explained.

[0054] This semiconductor laser has the laminated structure formed on the n-GaAs substrate 61 and the n-GaAs substrate 61. A laminated structure in an order from the side near the n-GaAs substrate 61 The n-Ga0.51In0.49P 1st clad layer 62, the GaAs 1st light closing ***** (Thickness:1.5micrometer) 63, the deformation amount child well barrier layer 64, GaAs 2nd light closing ***** (thickness:0.01micrometer) 65, the p-Ga0.51In0.49P 2nd clad layer 66, the n-GaAs current block layer (thickness:0.15micrometer) 67, a p-GaAs cap layer (Thickness:0.01micrometer) (Thickness:3micrometer) 68 is included. The p lateral electrode 69 is formed on the p-GaAs cap layer 68 of a laminated structure, and the n lateral electrode 70 is formed in the rear face of the n-GaAs substrate 61.

[0055] The deformation amount child well barrier layer 64 has the quantum well structure which In0.2Ga0.8As 1st well layer (thickness:7nm) 64a, GaAs barrier layer (thickness:10nm) 64b, and In0.2Ga0.8As 2nd well layer (thickness:7nm) 64c form.

[0056] The p-Ga0.51In0.49P 2nd clad layer 66 is divided into 1st layer partial (thickness:0.2micrometer) 66a which touches optical closing ***** , and 2nd layer partial (thickness:1.5micrometer) 66b which touches the p-GaAs cap layer 68. The n-GaAs current block layer 67 is located between 1st layer partial 66a of the p-Ga0.51In0.49P 2nd clad layer 66, and 2nd layer partial 66b.

[0057] The n-GaAs current block layer 67 is formed in fields other than the field corresponding to the predetermined field (current injection field) of the shape of a stripe of the deformation amount child well barrier layer 64. In other words, the n-GaAs current block layer 67 has stripe-like opening to the field corresponding to the current injection field of the deformation amount child well barrier layer 64. Width-of-face W of opening has specified the width of face of a current injection field. Although this width-of-face w is 6 micrometers typically, various values may be chosen from about 3 micrometers in the domain of about 8 micrometers. The n-GaAs current block layer 64 has a refractive index higher than the refractive index of the p-Ga0.51In0.49P 2nd clad layer 66, and has forbidden-band width of face larger than the forbidden-band width of face of a barrier layer 64.

[0058] The effective-refractive-index difference in the inside and outside of a stripe-like current injection field is controllable by adjusting thickness h of 1st layer partial 66a of the p-Ga0.51In0.49P 2nd clad layer 66, and thickness d of the n-GaAs current block layer 67. The thickness of 1st layer partial 66a of the p-Ga0.51In0.49P 2nd clad layer 66 may be chosen in the domain of about 0.05 to about 0.5 micrometers, and the thickness of the n-GaAs current block layer 67 may be chosen within the limits of about 0.02 to about 0.5 micrometers.

[0059] Also in the semiconductor laser of this example, the same effect as the semiconductor laser of this invention which has the structure mentioned above is acquired.

[0060] As the above-mentioned clad layer, you may use an $\text{Al}_x\text{Ga}_{1-x}\text{As}$ ($0.2 \leq x \leq 0.7$) layer or $(\text{Al}_x\text{Ga}_{1-x}) 0.51\text{In}_{0.49}\text{P}$ ($0 \leq x \leq 1$) layer. $(\text{Al}_x\text{Ga}_{1-x})$ When $0.51\text{In}_{0.49}\text{P}$ ($0 \leq x \leq 1$) layer is used for a clad layer, it is enabled to make the hetero barrier height between a barrier layer and a

clad layer higher than the height in this example. For this reason, the semiconductor laser which can operate stably at an elevated temperature is offered by adopting such a clad layer.

[0061] [Effect of the Invention] According to the semiconductor laser of this invention, to the exterior of the stripe of the clad layer of (1) semiconductor laser, the waveguide loss with a high and refractive index since a loss of a light according to absorption since a semiconductor layer larger than the forbidden-band width of face of a barrier layer is provided at least is small can be made small, and external differential quantum efficiency can obtain the semiconductor laser of the high power with the high stability of the basic transverse mode highly from the above-mentioned clad layer.

[0062] The process which carries out the laminating of the 1st clad layer, a barrier layer, and the 2nd clad layer one by one on (2) semiconductor substrate according to the manufacture technique of the semiconductor laser of this invention, A part of 2nd clad layer on the 2nd clad layer of the process processed into a trapezoid-like stripe, and the exterior of this stripe It has the process which carries out the laminating of at least two or more kinds of semiconductor layers in order to prevent injection of a current. Since it has the refractive index from which the two or more aforementioned kinds of semiconductor layers are different, a waveguide loss of light can be made small and external differential quantum efficiency can produce easily the semiconductor laser of the high power with the high stability of the basic transverse mode with sufficient repeatability highly.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The cross section of the transverse-mode control type red semiconductor laser of the example of this invention

[Drawing 2] Drawing showing an effective refractive index horizontal to the layer of the semiconductor laser of the example of this invention

[Drawing 3] Drawing showing the optical output of the semiconductor laser of the example of this invention, and the relation of a current

[Drawing 4] Drawing showing the relation between inverse number $1/\eta_D$ of external differential quantum efficiency, and a cavity length in drawing for explaining the effect of this invention

[Drawing 5] The 1st order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 6] The 2nd order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 7] The 3rd order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 8] The 4th order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 9] The 5th order cross section of a process showing the manufacturing process of the semiconductor laser of this invention

[Drawing 10] The cross section of the red semiconductor laser of the conventional example

[Drawing 11] Drawing explaining the difference of the threshold gain in this invention, the basic mode of the conventional example, and primary mode

[Drawing 12] Drawing showing the far field pattern of the semiconductor laser of this invention

[Drawing 13] Drawing showing the far field pattern of orientation level on each class of the semiconductor laser of this invention

[Drawing 14] Drawing showing the relation between the drive current of semiconductor laser, and an optical output which prepared the coating layer of 6% of reflection factors at the outgoing-radiation end face, and prepared 83% of the coating layer in other end faces in drawing showing the property of the semiconductor laser of this invention

[Drawing 15] Drawing showing the relation of the optical output which generates stripe width of face and a kink about the semiconductor laser of this invention

[Drawing 16] The cross section of the transverse-mode control type semiconductor laser of another example of this invention

[Description of Notations]

- 1 N-GaAs Substrate
- 2 N-GaAs Buffer Layer
- 3 N-(Aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P Clad Layer
- 4 Ga_{0.51}In_{0.49}P Barrier Layer
- 5 P-(Aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P Clad Layer
- 6 P-Ga_{0.51}In_{0.49}P Layer
- 7 N-(Aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P Layer
- 8 N-(Aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P Layer
- 9 P-GaAs Cap Layer
- 10 P Lateral Electrode
- 11 N Lateral Electrode
- 12 SiO₂
- 13 N-GaAs Current Block Layer
- 61 N-GaAs Substrate
- 62 N-Ga_{0.51}In_{0.49}P Clad Layer
- 63 GaAs Light Closing *****
- 64 Deformation Amount Child Well Barrier Layer
- 64a In_{0.2}Ga_{0.8}As -- a well -- a layer
- 64b GaAs barrier layer
- 64c In_{0.2}Ga_{0.8}As -- a well -- a layer
- 65 GaAs Light Closing *****
- 66 P-Ga_{0.51}In_{0.49}P Clad Layer
- 66a The 1st layer which touches optical closing *****
- 66b The 2nd layer which touches the p-GaAs cap layer 68
- 67 N-GaAs Current Block Layer
- 68 P-GaAs Cap Layer
- 69 P Lateral Electrode
- 70 N Lateral Electrode

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(54) SEMICONDUCTOR LASER AND FABRICATION THEREOF

(57) Abstract:

PURPOSE: To provide a high output semiconductor laser having oscillation wavelength in visible light region in which differential quantum efficiency is enhanced while enhancing the stability of transverse mode.

CONSTITUTION: A p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49} clad layer 5 of semiconductor laser is partially formed into a trapezoidal stripe. An n-(Al_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and an n-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 are deposited on a p-(Al_{0.7}Ga_{0.3})_{0.51}In_{0.49}P clad layer 5 on the outside of the stripe. Effective refractive index in the trapezoidal stripe is set lower by 0.02 than that on the outside of the stripe.

* NOTICES *

JPO and NCIP are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.**** shows the word which can not be translated.

3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]

[Claim 1] It is the laminated structure formed on the semi-conductor substrate and this semi-conductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the cladding layer of the pair which sandwiches this barrier layer, and a

current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. This current constriction layer It has the 1st current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. This 1st current block layer Semiconductor laser which is the semi-conductor layer which has a refractive index higher than the refractive index of the cladding layer of this pair, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[Claim 2] It is the semiconductor laser to which said 1st current block layer has covered fields other than this stripe-like ridge on this cladding layer that has this stripe-like ridge by being semiconductor laser according to claim 1, and the cladding layer located among the cladding layers of said pair more nearly up than said barrier layer having the stripe-like ridge prolonged along the direction of a resonator of this semiconductor laser.

[Claim 3] Said current constriction layer is semiconductor laser according to claim 2 which is the semi-conductor layer which is further equipped with the 2nd current block layer prepared on said 1st current block layer, and has forbidden-band width of face with this 2nd current block layer larger than the forbidden-band width of face of said barrier layer.

[Claim 4] Semiconductor laser according to claim 3 whose cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a trapezoid.

[Claim 5] Semiconductor laser according to claim 3 whose cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a rectangle.

[Claim 6] It is the semiconductor laser according to claim 3 in which said semi-conductor substrate is formed in from GaAs, said barrier layer is formed in from GaInP, and said 1st and 2nd current block layer and the cladding layer of said pair are formed from AlGaInP.

[Claim 7] Said barrier layer is semiconductor laser according to claim 1 which has multiplex quantum well structure.

[Claim 8] One side of the cladding layers of said pair is semiconductor laser according to claim 1 which has the 1st layer part and the 2nd layer part which are crowded on both sides of said 1st current block layer.

[Claim 9] It is the semiconductor laser according to claim 8 in which said semi-conductor substrate is formed in from GaAs, said barrier layer contains the InGaAs layer in, the cladding layer of said pair is formed in from GaInP, and said 1st semi-conductor layer is formed from GaAs.

[Claim 10] Said barrier layer is semiconductor laser according to claim 8 which has multiplex quantum well structure.

[Claim 11] It is the approach of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semi-conductor substrate. This process [etch / these some film / the process which forms the 1st cladding layer, the process which forms a barrier layer on this 1st cladding layer, the process which forms the film used as the 2nd cladding layer on this barrier layer, and / furthermore, / alternatively] The stripe-like ridge section prolonged in the direction of a resonator of this semiconductor laser is formed in this film. The process which forms the 2nd cladding layer by it, and among this 2nd cladding layer, on parts other than this stripe-like ridge section The process which forms the 1st semi-conductor layer which has a refractive index higher than the refractive index of this 2nd cladding layer, and has

forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The manufacture approach of the semiconductor laser which includes the process which forms the 2nd semi-conductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semi-conductor layer.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001] [Industrial Application] Luminous efficiency of this invention is high and it relates to the semiconductor laser and its manufacture approach of the high power excellent in the stability of the basic transverse mode.

[0002] [Description of the Prior Art] The semiconductor laser which produces laser oscillation and emits light in a light field has applications, such as the light sources for optical information processing, such as a laser beam printer and an optical disk, and is increasing the importance recently. Especially, lattice matching of the ingredient of $0.5(\text{Al}_x\text{Ga}_{1-x})\text{In}_{0.5}\text{P}$ system is carried out to GaAs which is a good substrate ingredient, and since it can obtain the laser beam which has the wavelength of the arbitration within the limits of 0.68 to 0.56 micrometers by changing presentation x , it attracts attention.

[0003] Hereafter, the semiconductor laser which has oscillation wavelength with reference to drawing 10 to the red field of the transverse-mode control mold of the conventional double hetero structure is explained. This semiconductor laser is equipped with the n-GaAs buffer layer 2, the n-(aluminum $0.7\text{Ga}_{0.3}$) $0.51\text{In}_{0.49}\text{P}$ cladding layer 3, Ga $0.51\text{In}_{0.49}\text{P}$ barrier layer 4, the p- $0.51(\text{aluminum}0.7\text{Ga}_{0.3})\text{In}_{0.49}\text{P}$ cladding layer 5, p-Ga $0.51\text{In}_{0.49}\text{P}$ layer 6, the n-GaAs current block layer 13, and the p-GaAs cap layer 9 on the n-GaAs substrate 1 at this order, as shown in drawing 10. The p lateral electrode 10 is formed on the cap layer 9, and the n lateral electrode 11 is formed in the rear face of a substrate 1.

[0004] In this semiconductor laser, crystal growth techniques, such as metal-organic chemical vapor deposition (MOVPE law), are used. The sequential deposition of the n-GaAs buffer layer 2, the n-(aluminum $0.7\text{Ga}_{0.3}$) $0.51\text{In}_{0.49}\text{P}$ cladding layer 3, Ga $0.51\text{In}_{0.49}\text{P}$ barrier layer 4, the p-(aluminum $0.7\text{Ga}_{0.3}$) $0.51\text{In}_{0.49}\text{P}$ cladding layer 5, and p-Ga $0.51\text{In}_{0.49}\text{P}$ layer 6 is carried out on the n-GaAs substrate 1 using these crystal growth techniques.

[0005] Next, with a photolithography techniques and an etching technique, p-Ga $0.51\text{In}_{0.49}\text{P}$ layer 6 and the p-(aluminum $0.7\text{Ga}_{0.3}$) $0.51\text{In}_{0.49}\text{P}$ cladding layer 5 are etched into trapezoidal shape, and a stripe-like ridge is formed in a cladding layer 5. The n-GaAs current block layer 13 is alternatively deposited on the exterior of a stripe using the MOVPE method etc. after that, and the p-GaAs cap layer 9 is deposited further.

[0006] With the structure of such semiconductor laser, the n-GaAs current block layer 13 can perform the constriction of a current. In case the p-(aluminum $0.7\text{Ga}_{0.3}$) $0.51\text{In}_{0.49}\text{P}$ cladding layer 5 is etched on a trapezoid, moreover, by optimizing trapezoid height and width of face The effective-refractive-index difference with which are satisfied of the conditions of single transverse mode can be given within and without the stripe of trapezoidal shape, and light can be effectively confined in the stripe-like ridge lower part of a cladding layer 5 among barrier layers 4. The width of face of a stripe is about 5 micrometers typically.

[0007] [Problem(s) to be Solved by the Invention] However, with the structure of the conventional example, GaAs with forbidden-band width of face smaller than a barrier layer is used as a current block layer. For this reason, this GaAs layer works as an absorption-of-light layer. Therefore, loss of the light by absorption is large and guided wave loss α_{guide} in case light guides the inside of the resonator of semiconductor laser becomes large with abbreviation 15cm-1. Consequently, the external differential quantum efficiency of semiconductor laser becomes small with about 60%. Moreover, in this semiconductor laser, kink level is as small as about 12mW. Although a kink is produced when the transverse mode changes, with the structure of drawing 10, it is for the mode to become easy to change with the increments in an inrush current easily so greatly [the difference of the gain in a basic mode and the high order mode]. Since external differential quantum efficiency is small and the stability of the basic transverse mode is low, with the structure of the conventional example, it is hard to obtain semiconductor laser with a high optical output.

[0008] The purpose of this invention is offering the semiconductor laser of high power with the high stability of the basic transverse mode which solves such a technical problem and has high external differential quantum efficiency, and its manufacture approach.

[0009] [Means for Solving the Problem] The semiconductor laser of this invention is the laminated structure formed on the semi-conductor substrate and this semi-conductor substrate. A barrier layer, It is the semiconductor laser equipped with the laminated structure which has the cladding layer of the pair which sandwiches this barrier layer, and a current constriction layer for pouring a current into the stripe-like predetermined field of this barrier layer. This current constriction layer It has the 1st current block layer formed in fields other than the field corresponding to this predetermined field of this barrier layer. This 1st current block layer It is the semi-conductor layer which has a refractive index higher than the refractive index of the cladding layer of this pair, and it has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, and the above-mentioned purpose is attained by that.

[0010] In a certain example, the cladding layer located among the cladding layers of said pair more nearly up than said barrier layer has the stripe-like ridge prolonged along the direction of a resonator of this semiconductor laser, and said 1st current block layer has covered fields other than this stripe-like ridge on this cladding layer that has this stripe-like ridge.

[0011] In a certain example, said current constriction layer is further equipped with the 2nd current block layer prepared on said 1st current block layer, and this 2nd current block layer is a semi-conductor layer which has forbidden-band width of face larger than the forbidden-band width of face of said barrier layer.

[0012] In a certain example, the cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a trapezoid.

[0013] In a certain example, the cross section of said stripe-like ridge about a field perpendicular to said direction of a resonator is a rectangle.

[0014] In a certain example, said semi-conductor substrate is formed from GaAs, said barrier layer is formed from GaInP, and said 1st and 2nd current block layer and the cladding layer of said pair are formed from AlGaInP.

[0015] One side of the cladding layers of said pair may have the 1st layer part and the 2nd layer part which are crowded on both sides of said 1st current block layer.

[0016] In a certain example, said semi-conductor substrate is formed from GaAs, said barrier layer contains the InGaAs layer, the cladding layer of said pair is formed from GaInP, and said 1st semi-conductor layer is formed from GaAs.

[0017] Said barrier layer may have multiplex quantum well structure. The manufacture approach of the semiconductor laser of this invention is an approach of manufacturing the semiconductor laser which includes the process which forms a laminated structure on a semi-conductor substrate. This process The process which forms the 1st cladding layer, the process which forms a barrier layer on this 1st cladding layer, the process which forms the film used as the 2nd cladding layer on this barrier layer, and by etching these some film alternatively The stripe-like ridge section prolonged in the direction of a resonator of this semiconductor laser is formed in this film. The process which forms the 2nd cladding layer by it, and among this 2nd cladding layer, on parts other than this stripe-like ridge section The process which forms the 1st semi-conductor layer which has a refractive index higher than the refractive index of this 2nd cladding layer, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer, The process which forms the 2nd semi-conductor layer which has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer on this 1st semi-conductor layer is included, and the above-mentioned purpose is attained by that.

[0018] [Function] The current constriction layer of this invention is equipped with the 1st current block layer formed in fields other than the field corresponding to the stripe-like predetermined field of a barrier layer. This 1st current block layer has a refractive index higher than the refractive index of the cladding layer of a pair, and has forbidden-band width of face larger than the forbidden-band width of face of this barrier layer.

[0019] The 1st current block layer has the function which prevents that a current flows into a barrier layer. For this reason, a current is alternatively poured only into the predetermined field of the barrier layer corresponding to the field to which the 1st current block layer does not exist. Consequently, a laser beam occurs only in the stripe-like predetermined field of a barrier layer. A part of this laser beam leaks in the vertical direction from a barrier layer, and it reaches a cladding layer and the 1st current block layer. Since the 1st current block layer has the refractive index higher than the refractive index of a barrier layer, a laser beam leaks from a predetermined stripe-like field to a longitudinal direction. Generally this reason is that light gathers in the field where a refractive index is high.

[0020] the laser beam oscillated in the basic level transverse mode, and the laser beam oscillated in the high order level transverse mode -- comparing -- a case -- the high order level transverse mode -- oscillating -- a laser beam -- the direction is widely distributed by the longitudinal direction. For this reason, in the semiconductor laser of this invention, extent which leaks from a predetermined stripe-like field to a longitudinal direction is stronger than the laser beam which the direction of the laser beam oscillated in the high order level transverse mode oscillates in the basic level transverse mode. It emits and the laser beam oscillated in the high order level transverse mode stops for this reason, contributing to laser oscillation. In other words, the laser beam oscillated in the high order level transverse mode will have higher threshold gain by existence of the 1st current block layer as compared with the laser beam oscillated in the basic level transverse mode. Consequently, only the laser beam oscillated in the basic level transverse mode can be obtained alternatively.

[0021] Moreover, since it has forbidden-band width of face with the 1st current block layer larger than the forbidden-band width of face of a barrier layer, the laser beam generated in the barrier layer is not absorbed by the 1st current block layer. For this reason, propagation loss of racer light is reduced as compared with the conventional semiconductor laser.

[0022] As explained above, the semiconductor laser of this invention can oscillate the laser beam of the basic level transverse mode by low propagation loss.

[0023] [Example] (Example 1) The example of this invention is explained hereafter, referring to a drawing.

[0024] The sectional view of the red semiconductor laser of the transverse-mode control mold of one example of this invention is shown in drawing 1 .

[0025] This semiconductor laser has the double hetero structure which sandwiches Ga_{0.51}In_{0.49}P barrier layer 4 (600Å in thickness) through the n-GaAs buffer layer 2 by the n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 3 and the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 5 on the n-GaAs substrate 1, as shown in drawing 1 . In the upper part of the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 5, it has p-Ga_{0.51}In_{0.49}P layer 6 (1000Å in thickness), and a part of p-Ga_{0.51}In_{0.49}P layer 6 and p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 5 is processed into the stripe-like ridge of trapezoidal shape. In a cladding layer 5, the thickness of parts other than 1.3 micrometers and a stripe-like ridge part of the thickness of a stripe-like ridge part is 0.25 micrometers.

[0026] On the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 5 of both the sides of a stripe-like ridge, n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 [700Å] and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 [0.7-micrometer] have accumulated. Furthermore, in the upper part of p-Ga_{0.51}In_{0.49}P layer 6 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8, it has the p-GaAs cap layer 9.

[0027] The width of face of the above-mentioned stripe-like ridge is the width of face which can take the large difference of the gain in the basic transverse mode and the high order mode, and the width of face has good about 7 micrometers. When extremely thinner than 7 micrometers, in the case of about 2 micrometers, leakage of the light to the outside of a stripe becomes large too much, the light which does not contribute to laser oscillation increases, the rise of a threshold current and loss become large, and decline in external differential quantum efficiency is brought about. Moreover, if stripe width of face becomes large too much, the difference of the gain in the basic transverse mode and the high order mode becomes small, or the ununiformity of impregnation of the carrier to Ga_{0.51}In_{0.49}P barrier layer 4 will be horizontal, and will arise, the fall of kink level will occur, and practical use will not be borne.

[0028] Moreover, although the cross-section configuration of a stripe-like ridge is a trapezoid in this example, this cross-section configuration may be a rectangle. In that case, it is desirable not to form layers 7 and 8 on the side face of a ridge.

[0029] The horizontal effective refractive index decided by the configuration of each class of this semiconductor laser is shown in drawing 2 . the effective refractive index inside a stripe-like ridge -- the effective refractive index of the exterior of 3.307 and a stripe-like ridge -- 3.329 -- it is -- external one -- 0.022 -- it is high. This effective-refractive-index difference is brought about by n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 [700Å] and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 [0.7-micrometer]. The difference of big gain arises between the basic transverse mode

and the high order mode because of this effective-refractive-index difference. For this reason, since it is hard to generate a kink even if it enlarges the amount of an inrush current, a high optical output can be obtained in the condition that there is no kink.

[0030] It is shown in drawing 11 that the difference of big gain has arisen between a basic mode and the higher mode because of the effective-refractive-index difference brought about by n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 here. Drawing 11 takes stripe width of face along an axis of abscissa, and takes the threshold gain g_{th} along an axis of ordinate. The difference of threshold gain with the primary mode ($m=1$) was indicated about each of (a) this invention and the (b) conventional example as a basic mode ($m=0$) and the higher mode to this drawing. The higher mode [like / the difference of the threshold gain in a basic mode and the primary mode is small, and / the primary mode] it is tends to produce the laser of the conventional example of (b) so that this drawing 11 may show. On the other hand, the laser (b) of this invention has the large difference of the threshold gain in a basic mode and the primary mode, and cannot produce the higher mode like the primary mode easily.

[0031] Drawing 14 shows the relation between a drive current (CURRENT) and an optical output (OUTPUT POWER) about the semiconductor laser of this invention. Coating of the outgoing radiation end face was carried out with the film of 6% of reflection factors, and the data shown in this graph were obtained about the semiconductor laser to which coating of other end faces was carried out with the film of 83% of reflection factors. The cavity length of semiconductor laser is 500micro. The optical output is increasing linearly according to the increment in a drive current until an optical output exceeds about 65mW, but after an optical output exceeds about 65mW, extent of the increment in an optical output falls temporarily. As mentioned above, in a graph, such a part is called "kink." When it is below in level with an optical output, a kink occurs, because the laser beam which that only the laser beam in a basic mode ($m=1$) was oscillating has in the laser beam in the modes other than a basic mode (the high order mode: $m \geq 2$) and a basic mode when an optical output exceeds the level (it is called "kink level") begins to be intermingled. Semiconductor laser with higher kink level can stabilize for it and supply the laser beam in a basic mode in a high optical output. KIN ** level becomes high, so that the difference of the threshold gain about the laser beam in a basic mode ($m=1$) and the threshold gain about the laser beam in other modes ($m \geq 2$) is large.

[0032] Drawing 15 is a graph which shows the relation between the width of face of the stripe ridge of a cladding layer 4, and the level of the optical output which a kink generates about the semiconductor laser of this invention which has the structure shown in drawing 1 .

[0033] Each cavity length of the semiconductor laser used for measurement is 350 micrometers, and coating of the reflective film etc. is not carried out to the both-ends side of each semiconductor laser. The semiconductor laser of this invention has high kink level as compared with the conventional semiconductor laser so that drawing 15 may show. This shows that the difference of the threshold gain of a basic mode ($m=1$) and the threshold gain in other modes ($m \geq 2$) is large rather than it can set to the conventional semiconductor laser in the semiconductor laser of this invention.

[0034] Moreover, n-(aluminum0.2Ga0.8)0.51In0.49P layer 7 and n-(aluminum0.7Ga0.3)0.51In0.49P layer 8 block the current which flows from the p lateral electrode 10, they carry out the constriction of the current into the stripe-like ridge of a cladding

layer 5, and also possess the work which pours a current into the predetermined field of a barrier layer 4 by it.

[0035] In this invention, 700A n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and two kinds of 0.7-micrometer semi-conductor layers of n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 are used in order to prepare a refractive-index difference within and without the stripe of trapezoidal shape. The layer [1st] semi-conductor layer, i.e., the refractive index of n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7, is larger than the refractive index of the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 5. A cladding layer and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 with an almost equal refractive index are used for the two-layer eye. Light is influenced of the refractive index of only the ingredient near the barrier layer 4. A stable effective refractive index can be obtained in the exterior of a stripe. The effective-refractive-index difference in desired stripe inside and outside is easily acquired by changing the thickness of n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7. That is, it will become small if an effective-refractive-index difference will become large if n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 becomes thick, and it becomes thin. The refractive-index difference in the stripe inside and outside is controlled by adjustment of the thickness of n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 in 0.01-0.05.

[0036] Moreover, although the 1st-layer aluminum presentation was set to 0.2 here, even if it changes this aluminum presentation, an effective-refractive-index difference can be changed. That is, if an effective-refractive-index difference will become large if aluminum presentation becomes small, and aluminum presentation becomes large, an effective-refractive-index difference will become small.

[0037] the ingredient 0.49 with it, for example, n-(aluminum_{0.55}Ga_{0.45})_{0.51}In, -- the fluctuation of the presentation of P layers -- there is nothing -- homogeneity -- and it needs to be thick, for example, it is necessary to deposit 1 micrometers or more [a refractive index higher than that of the p-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P cladding layer 5 and, and] [very near in order to give the same effective-refractive-index difference in one kind of semi-conductor layer] In this case, since light leaks deeply into n-(aluminum_{0.55}Ga_{0.45})_{0.51}In_{0.49}P layer, light is influenced of the refractive index in the location distant distantly [barrier layer / 4]. Moreover, if it shifts from the set point, n-(aluminum_{0.55}Ga_{0.45})_{0.51}In_{0.49}P layer a presentation, i.e., a refractive index, the effective refractive index in the inside and outside of a stripe will shift. Moreover, if the thickness is thin, the light produced in Ga_{0.51}In_{0.49}P barrier layer 4 will be absorbed by the p-GaAs cap layer 9, and loss of light energy will arise. Therefore, a possibility that the stability when producing semiconductor laser and repeatability may become low arises. In order to make a desired effective-refractive-index difference with sufficient repeatability correctly, it is desirable to prepare two or more kinds of semi-conductor layers.

[0038] The optical output of this semiconductor laser and the relation of the current poured into semiconductor laser are shown in drawing 3 . At this semiconductor laser, an optical output can be obtained in the condition that there is no kink to about 30mW. Moreover, external differential-quantum-efficiency η_D of this semiconductor laser is as high as 85%. Since a horizontal effective-refractive-index difference is given, it is because n-(aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P layer 7 and n-(aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P layer 8 are used. This two-layer forbidden-band width of face is larger than that of Ga_{0.51}In_{0.49}P barrier layer 4. Therefore, the light generated in Ga_{0.51}In_{0.49}P barrier layer 4 is not absorbed,

therefore, as a result, guided wave loss α_{g} can acquire high external differential quantum efficiency small. Drawing 4 is an experimental result for investigating guided wave loss, and is drawing showing the relation of the cavity length of inverse number $1/\eta_{\text{D}}$ of external differential quantum efficiency, and semiconductor laser. Proportionality is between $1/\eta_{\text{D}}$ and cavity length, and guided wave loss can be derived from this inclination with 4.2cm^{-1} . Since guided wave loss of the semiconductor laser of the conventional example is abbreviation 15cm^{-1} , the semiconductor laser of this invention will take the value of $1/3 - 1/4$. Therefore, it can explain that the external differential quantum efficiency of the semiconductor laser of this invention is high.

[0039] As explanation of the semiconductor laser of this invention having a good property next, the result of having measured the far field pattern of this invention is shown in drawing 12 .

[0040] (a) is output luminous-intensity distribution over the include angle of a direction level on each class of semiconductor laser, and (b) shows the output luminous-intensity distribution over the include angle of a direction perpendicular to each class.

[0041] Small Said Rob is seen beside the peak of Maine of a far field pattern horizontal to each class of (a). Although this Said Rob is the description of the semiconductor laser of this invention, it is not that this semiconductor laser is oscillating by the higher mode, and depends for the light which leaked out of the ridge stripe.

[0042] Thus, it turns out that both the semiconductor laser of this invention is oscillated by the basic mode from the far field pattern.

[0043] In addition, drawing 13 explained plainly the peak of Maine shown in drawing 12 , and Said Rob. It is luminous-intensity distribution of a direction level on each class of semiconductor laser.

[0044] As stated above, the semiconductor laser of high power can be obtained from high basic transverse-mode stability and high external differential quantum efficiency.

[0045] Below, drawing 9 is used from drawing 5 $R > 5$, and the production approach of this semiconductor laser is explained. First, the n-GaAs buffer layer 2, the n-(aluminum $_{0.7}$ Ga $_{0.3}$) $_{0.51}$ In $_{0.49}$ P cladding layer 3, Ga $_{0.51}$ In $_{0.49}$ P barrier layer 4, the p-(aluminum $_{0.7}$ Ga $_{0.3}$) $_{0.51}$ In $_{0.49}$ P cladding layer 5, and p-Ga $_{0.51}$ In $_{0.49}$ P layer 6 are grown epitaxially on the n-GaAs substrate 1 using the crystal growth approaches, such as the MOVPE method, (drawing 5). After making SiO $_2$ deposit on p-Ga $_{0.51}$ In $_{0.49}$ P layer 6, a part of SiO $_2$, p-Ga $_{0.51}$ In $_{0.49}$ P layer 6, and p-(aluminum $_{0.7}$ Ga $_{0.3}$) $_{0.51}$ In $_{0.49}$ P cladding layer 5 are processed into the stripe of trapezoidal shape using a photolithography techniques and an etching technique (drawing 6 $R > 6$). MOVPE after processing trapezoidal shape -- crystal growth is carried out on the p-(aluminum $_{0.7}$ Ga $_{0.3}$) $_{0.51}$ In $_{0.49}$ P cladding layer 5 of both the sides of a stripe, without making n-(aluminum $_{0.2}$ Ga $_{0.8}$) $_{0.51}$ In $_{0.49}$ P layer 7 and n-(aluminum $_{0.7}$ Ga $_{0.3}$) $_{0.51}$ In $_{0.49}$ P layer 8 deposit on SiO $_2$ as a current block layer using the selective growth technique of law (drawing 7). Then, SiO $_2$ is removed and crystal growth of the p-GaAs cap layer 9 is carried out (drawing 8). Finally Cr/Pt/Au is deposited on the p-GaAs contact layer 9, it considers as the p lateral electrode 10, Au/germanium/nickel is deposited on the n-GaAs substrate 1, and it considers as the n lateral electrode 11 (drawing 9).

[0046] By such manufacture approach, the red semiconductor laser of a transverse-mode control mold as shown in drawing 1 is producible.

[0047] In addition, by this example, in order to establish an effective-refractive-index difference within and without the stripe of trapezoidal shape, two kinds of semi-conductor layers were used and explained, but even if it uses three or more kinds, an effective refraction difference can be made.

[0048] the above-mentioned example -- the effective refractive index inside the stripe of trapezoidal shape -- it of the exterior of a stripe -- 0.022 -- although it is made low, if the range of this effective-refractive-index difference is 0.01 to 0.05, the effectiveness of this invention is large. However, if an effective-refractive-index difference changes, according to it, the stripe width of face of trapezoidal shape must also be changed.

[0049] In addition, the effective refractive index of the part besides a stripe-like ridge is controllable by changing thickness [of the stripe-like ridge exterior of a cladding layer 5] h, and the thickness of a layer 7. The range of the thickness of 0.02-0.5 micrometers and a layer 8 has [the range of the thickness of h / the range of the thickness of 0.05-0.5 micrometers and a layer 7] desirable 0.3-1 micrometer.

[0050] Although the ingredient which constitutes semiconductor laser from an above-mentioned example was specified, also by the case of $0.51(\text{Al}_z\text{Ga}_{1-z})\text{In}_{0.49}\text{P}$ (here, it is $0 \leq z \leq y \leq 1$), $0.51(\text{Al}_y\text{Ga}_{1-y})\text{In}_{0.49}\text{P}$ and a barrier layer have large external differential quantum efficiency, and a cladding layer can produce easily the semiconductor laser of high power with high transverse-mode stability.

[0051] Moreover, although the above-mentioned example explained the semiconductor laser which used AlGaInP for the ingredient, it cannot be overemphasized that other ingredients have the large effectiveness of this invention. Not only an III-V group's semiconductor laser but the semiconductor laser of this effect of the invention which consists of an II-VI group's ingredient is large.

[0052] Although the barrier layer of the above-mentioned example is formed of the monolayer of an AlGaInP semi-conductor, the barrier layer which has multiplex quantum well structure may be used. As such a barrier layer, for example A Ga_{0.44}In_{0.56}P well layer (8nm in thickness), A 0.51In_{0.49}P barrier layer (5nm in thickness), (aluminum_{0.45}Ga_{0.55}) A Ga_{0.44}In_{0.56}P well layer (8nm in thickness), a 0.51(aluminum_{0.45}Ga_{0.55}) In_{0.49}P barrier layer (5nm in thickness), and the barrier layer included the Ga_{0.44}In_{0.56}P well layer (8nm in thickness) may be used. Since 0.5% of compressive strain has arisen in three well layers, such a barrier layer is called a distorted multiplex quantum well barrier layer. This multiplex quantum well barrier layer is sandwiched by the 0.51(aluminum_{0.45}Ga_{0.55}) In_{0.49}P optical confinement layer (10nm in thickness) of the pair which touches a cladding layer.

[0053] (Example 2) With reference to drawing 16, other semiconductor laser by this invention is explained.

[0054] This semiconductor laser has the laminated structure formed on the n-GaAs substrate 61 and the n-GaAs substrate 61. A laminated structure in an order from the side near the n-GaAs substrate 61 The n-Ga_{0.51}In_{0.49}P 1st cladding layer 62, the 1st optical confinement layer of GaAs (Thickness: 1.5 micrometers) 63, the deformation amount child well barrier layer 64, the 2nd optical confinement layer (thickness: 0.01 micrometers) 65 of GaAs, the p-Ga_{0.51}In_{0.49}P 2nd cladding layer 66, the n-GaAs current block layer (thickness: 0.15 micrometers) 67, a p-GaAs cap layer (Thickness: 0.01 micrometers) (Thickness: 3 micrometers) 68 is included. The p

lateral electrode 69 is formed on the p-GaAs cap layer 68 of a laminated structure, and the n lateral electrode 70 is formed in the rear face of the n-GaAs substrate 61.

[0055] The deformation amount child well barrier layer 64 has the quantum well structure which 1st well layer (thickness: 7nm) of In_{0.2}Ga_{0.8}As 64a, GaAs barrier layer (thickness: 10nm) 64b, and 2nd well layer (thickness: 7nm) of In_{0.2}Ga_{0.8}As 64c form.

[0056] The p-Ga_{0.51}In_{0.49}P 2nd cladding layer 66 is divided into 1st layer partial (thickness: 0.2 micrometers) 66a which touches an optical confinement layer, and 2nd layer partial (thickness: 1.5 micrometers) 66b which touches the p-GaAs cap layer 68. Between 1st layer partial 66a of the p-Ga_{0.51}In_{0.49}P 2nd cladding layer 66, and 2nd layer partial 66b, the n-GaAs current block layer 67 is located.

[0057] The n-GaAs current block layer 67 is formed in fields other than the field corresponding to the predetermined field (current impregnation field) of the shape of a stripe of the deformation amount child well barrier layer 64. In other words, the n-GaAs current block layer 67 has stripe-like opening to the field corresponding to the current impregnation field of the deformation amount child well barrier layer 64. The width of face W of opening has specified the width of face of a current impregnation field. Although this width of face w is 6 micrometers typically, various values may be chosen from about 3 micrometers in the range of about 8 micrometers. The n-GaAs current block layer 64 has a refractive index higher than the refractive index of the p-Ga_{0.51}In_{0.49}P 2nd cladding layer 66, and has forbidden-band width of face larger than the forbidden-band width of face of a barrier layer 64.

[0058] The effective-refractive-index difference in the inside and outside of a stripe-like current impregnation field is controllable by adjusting thickness [of 1st layer partial 66a of the p-Ga_{0.51}In_{0.49}P 2nd cladding layer 66] h, and thickness d of the n-GaAs current block layer 67. The thickness of 1st layer partial 66a of the p-Ga_{0.51}In_{0.49}P 2nd cladding layer 66 may be chosen from about 0.05 micrometers in the range of about 0.5 micrometers, and the thickness of the n-GaAs current block layer 67 may be chosen from about 0.02 micrometers within the limits of about 0.5 micrometers.

[0059] Also in the semiconductor laser of this example, the same effectiveness as the semiconductor laser of this invention which has the structure mentioned above is acquired.

[0060] As the above-mentioned cladding layer, an Al_xGa_{1-x}As (0.2≤x≤0.7) layer or (Al_xGa_{1-x})_{0.51}In_{0.49}P (0≤x≤1) layer may be used. (Al_xGa_{1-x}) When 0.51In_{0.49}P (0≤x≤1) layer is used for a cladding layer, it becomes possible to make the hetero barrier height between a barrier layer and a cladding layer higher than the height in this example. For this reason, the semiconductor laser which can operate to stability at an elevated temperature more is offered by adopting such a cladding layer.

[0061] [Effect of the Invention] According to the semiconductor laser of this invention, to the exterior of the stripe of the cladding layer of (1) semiconductor laser, since a semi-conductor layer with it is provided at least from the above-mentioned cladding layer, since loss of the light by absorption is small, guided wave loss can be made small, and external differential quantum efficiency can obtain the semiconductor laser of the extremely stable high power of the basic transverse mode highly. [a high and refractive index and] [larger than the forbidden-band width of face of a barrier layer]

[0062] The process which carries out the laminating of the 1st cladding layer, a barrier layer, and the 2nd cladding layer one by one on (2) semi-conductor substrate according to the manufacture approach of the semiconductor laser of this invention, A part of 2nd cladding layer on the 2nd cladding layer of the process processed into the stripe of trapezoidal shape, and the exterior of this stripe It has the process which carries out the laminating of at least two or more kinds of semi-conductor layers in order to prevent impregnation of a current. Since it has the refractive index from which said two or more kinds of semi-conductor layers differ, guided wave loss of light can be made small and external differential quantum efficiency can produce easily the semiconductor laser of the extremely stable high power of the basic transverse mode with sufficient repeatability highly.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The sectional view of the red semiconductor laser of the transverse-mode control mold of the example of this invention

[Drawing 2] Drawing showing an effective refractive index horizontal to the layer of the semiconductor laser of the example of this invention

[Drawing 3] Drawing showing the optical output of the semiconductor laser of the example of this invention, and the relation of a current

[Drawing 4] Drawing showing $1/\eta_D$ of inverse numbers of external differential quantum efficiency, and the relation of cavity length in drawing for explaining the effectiveness of this invention

[Drawing 5] The 1st order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 6] The 2nd order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 7] The 3rd order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 8] The 4th order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 9] The 5th order sectional view showing the production process of the semiconductor laser of this invention of a process

[Drawing 10] The sectional view of the red semiconductor laser of the conventional example

[Drawing 11] Drawing explaining the difference of the threshold gain in this invention, the basic mode of the conventional example, and the primary mode

[Drawing 12] Drawing showing the far field pattern of the semiconductor laser of this invention

[Drawing 13] Drawing showing the far field pattern of a direction level on each class of the semiconductor laser of this invention

[Drawing 14] Drawing showing the drive current of the semiconductor laser which prepared the coating film of 6% of reflection factors in the outgoing radiation end face, and prepared 83% of coating film in other end faces, and the relation of an optical output in drawing showing the property of the semiconductor laser of this invention

[Drawing 15] Drawing showing stripe width of face and the relation of the optical output which generates a kink about the semiconductor laser of this invention

[Drawing 16] The sectional view of the semiconductor laser of the transverse-mode control mold of another example of this invention

[Description of Notations]

- 1 N-GaAs Substrate
- 2 N-GaAs Buffer Layer
- 3 N-(Aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P Cladding Layer
- 4 Ga_{0.51}In_{0.49}P Barrier Layer
- 5 P-(Aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P Cladding Layer
- 6 P-Ga_{0.51}In_{0.49}P Layer
- 7 N-(Aluminum_{0.2}Ga_{0.8})_{0.51}In_{0.49}P Layer
- 8 N-(Aluminum_{0.7}Ga_{0.3})_{0.51}In_{0.49}P Layer
- 9 P-GaAs Cap Layer
- 10 P Lateral Electrode
- 11 N Lateral Electrode
- 12 SiO₂
- 13 N-GaAs Current Block Layer
- 61 N-GaAs Substrate
- 62 N-Ga_{0.51}In_{0.49}P Cladding Layer
- 63 GaAs Optical Confinement Layer
- 64 Deformation Amount Child Well Barrier Layer
- 64a In_{0.2}Ga_{0.8}As -- a well -- a layer
- 64b GaAs barrier layer
- 64c In_{0.2}Ga_{0.8}As -- a well -- a layer
- 65 GaAs Optical Confinement Layer
- 66 P-Ga_{0.51}In_{0.49}P Cladding Layer
- 66a The 1st layer which touches an optical confinement layer
- 66b The 2nd layer which touches the p-GaAs cap layer 68
- 67 N-GaAs Current Block Layer
- 68 P-GaAs Cap Layer
- 69 P Lateral Electrode
- 70 N Lateral Electrode